# Mineral nutrition and its genetic signature in oil palm (*Elaeis guineensis* Jacq.): a possible panorama for high yielding materials at low fertiliser cost[1]

J.Ch. Jacquemard[2], J. Ollivier[3], Erwanda[4], Edyana Suryana[3]

and Pepep Permadi[3]

## ABSTRACT

*Significant differences in the mineral nutrition have been demonstrated between progenies and the main categories at PT Socfindo (Jacquemard et al, 2002). A new set of investigations has been conducted based on a larger genetic background. It includes 489 progenies observed in 25 genetic trials planted at Aek Loba Timur Project and 63 commercial blocs covering around 3500 hectares dispatched through all the PT Socfindo estates.*

*The leaf contents in the major elements constitute an important genetic signature that allows the characterization and the individualization of the nutritional level of each ALT project families according their genetic background.*

*The observations achieved on the commercial blocs confirm the signature of ALT project derived commercial categories. Some large groups show very distinct characteristics in their nutrient levels such as:*

- *Low nitrogen – low potassium*
- *Low nitrogen – high potassium*
- *High nitrogen – low potassium*

*In addition, some high yielding families express a specific behavior linking calcium to their chlorine absorption, then limiting the potassium absorption. The relation-ship between all these elements is discussed.*

*Providing of high yielding planting material more frugal in fertilizer input is discussed. This possible panorama offered to research and oil palm sector is an added value on the way of sustainable palm oil.*

Key words:

*Elaeis guineensis, mineral nutrition, genetic background, fertilization*

Corresponding author: jacquemard@indosat.net.id

[1] Paper presented at IOPC 2010 "Transforming Oil Palm Industry". 1 – 3 June 2010, Jogja Expo Center, Yogyakarta - Indonesia

[2] PT Socfindo Medan / UR Oil Palm Breeding – Cirad Bios, PO Box 1254 – Medan 20001 – Sumatera Utara – Indonesia

[3] UR Performance of tree-crop-based systems – Cirad Persyst, TA B-34/02, Avenue Agropolis 34398 Montpellier Cedex 5 – France

[4] PT Socfindo Medan – PO Box 1254 – Medan 20001 – Sumatera Utara – Indonesia

# INTRODUCTION

Many factors may affect the oil palm leaf nutrient concentration and by the way, critical levels. An abundant literature is available for a large majority of them (Corley and Tinker, 2003). The soil and the age appear to be the most important. The effect of the soil is generally proven in all oil palm cultivation areas for all major and minor elements (Foster and Prabowo, 1996, Ollagnier et al, 1987). In other hand, the age is known to depress the leaf mineral contents. It is the case for nitrogen, phosphorus, potassium and magnesium (Hartley, 1988; Caliman et al, 1994).

The effect of the planting material has been investigated in several field experiments (Jacquemard et al, 2002). In 3 progeny trials planted at Aek Kwasan I Project (PT Socfindo), testing duras from LM404D selfed, LM404D x DA10D and DA115D selfed origins crossed by teneras and pisiferas from LM2T selfed, significant differences in the mineral leaf contents was proven for nitrogen, phosphorus, potassium and magnesium. From these trials and from an experiment carried out in nursery on (DA5D x DA3D) II x La Mé materials, significant differences between individual progenies were detected for the same elements.

In the experiments ALCP61 and ALCP62 (N3P3K3 subdivided for Mg), carried out with two different planting materials: (DA5D x DA3D) x LM2T selfed and (DA5D x DA3D) x LM311P, different critical level has been demonstrated for the potassium and suspected for the phosphorus (Jacquemard et al, 2002).

This paper would report new set of investigations based on larger genetic background including commercial planting materials. New results from ALCP61 and ALCP62 allowing possible way to produce planting materials combining high productivity and low fertiliser rate are submitted.

# EXPERIMENTS

## MATERIALS

The studied planting material comes from three PT Socfindo sources:

- Aek Loba Timur Project
- ALCP61 and ALCP 62
- Commercial planting material

Planted from 1995 to 2000, the Aek Loba Timur Project (ALT Project) includes 489 progenies planted in 25 progeny trials (Jacquemard et *al*, 2001). These progenies could be aggregated according their ancestor families: for the A Group, 18 families are identified and 24 families for the B Group (Table 1). The comparison in continuity between the trials is allowed through a special network of repeated progenies (Table 2). In addition, the CIRAD standard crosses (LM2T x DA10D and LM2T x DA115D) were planted in 1997 and 2000.

Table 1: Ancestor families tested at Aek Loba Timur Project

| A Group origins | Ancestors |
|---|---|
| Socfindo | BB126DxBB150D |
| | BB177DxBB129D |
| | BB206Dselfed |
| Dabou | DA10DxDA115D |
| | DA10DxDA3D |
| | DA115D II |
| | DA115Dselfed |
| | DA115DxDA3D |
| | DA300DxDA128D |
| | DA551DxDA767D |
| | DA5DxDA3D II |
| | DABOU |
| Socfin x Dabou | LM269DxDA115D |
| | LM269DxDA128D |
| | LM404DxDA10D |
| | LM404DxDA3D |
| Socfin | LM404Dselfed |
| Angola x Socfin | TNR115xLM630D |

| B Group Origins | Ancestors |
|---|---|
| Illegitimate | ?xLM9T |
| | FR10 |
| | FR9 |
| | LM2TxLM231T |
| | LM2TxLM269D |
| | LM426Tselfed |
| | LM430Tselfed |
| Socfindo | BB85Tselfed |
| | BB85TxBB20P |
| La Mé | LA ME |
| | LM10Tselfed |
| | LM2T II |
| | LM2Tselfed |
| | LM2TxLM10T |
| | LM2TxLM5T |
| | LM2TxSI10T |
| | LM5Tselfed |
| | LM5TxLM10T |
| | LM5TxLM2T |
| | LM5TxLM311P |
| Yangambi | LM238TxLM511P |
| | PO4157T (LM718Tselfed) |
| | LM718TxLM238T |
| Nifor | PO1879TxPO1876T |

, The families highlighted in yellow are also planted in commercial blocks that are used for our analyse in the commercial plantings.

Table 2: Network of repeated progenies

| | 1995 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| **1995** | 3 | 7 | 0 | 0 | 4 |
| **1997** | 7 | 21 | 8 | 2 | 6 |
| **1998** | 0 | 8 | 6 | 6 | 5 |
| **1999** | 0 | 2 | 6 | 4 | 2 |
| **2000** | 4 | 6 | 5 | 2 | 2 |

ALCP61 and ALCP62, set up side by side at the Aek Loba plantation (North Sumatra), with two types of planting materials, study the effect of four fertilisers on the mineral nutrition and the production (Jacquemard et *al*, 2002). The purpose is to deduce the most appropriate fertiliser schedules.

The first trial (ALCP 61) is planted with (DA5D x DA3D) x LM2T selfed material, the second (ALCP 62) with (DA5D x DA3D) x LM311P material. LM311P is a pisifera of LM6, an illegitimate progeny of LM2T. The trial was set up on palms planted in 1989.

The design comprises 3 factors N, P and K studied on 3 levels. N, P and K applications are in a ratio of 0, 1 and 3. The subdivision for magnesium was launched in 1997 (Table 3).

Table 3: Factors studied (kg / palm / year)

| | Level 0 | Level 1 | Level 2 |
|---|---|---|---|
| **Urea** | 0.0 | 1.0 | 3.0 |
| **Rock Phosphate** | 0.0 | 0.5 | 1.5 |
| **KCl** | 1.0 | 2.0 | 4.0 |
| **Dolomite CP 61** | | 0.5 | 1.0 |
| **Dolomite CP 62** | 0.0 | 0.5 | |

At the same time as the genetic trials were established, numerous categories reproducing some of listed families (Table 1) were distributed across nine PT Socfindo oil palm estates in the North Sumatra and Aceh provinces. Unfortunately, all the ancestor families tested at the ALT project have not been planted in commercial blocs, which allow a comparison for some of them only.

## METHODS

The nutritional status data are specifically obtained by the leaf content analyses. The CIRAD standard method of collection and analyse has been used (Ochs and Ollivin, 1977). The samples have been taken from the leaf 17 and analysed at the CIRAD laboratory. The analysed elements are nitrogen, phosphorus, potassium, calcium, magnesium, chlorine and boron.

On the ALT project, the samples per progeny were taken every two years from 3 years old. To date, a complete set of data is available for 3, 5 and 7- years -old. The standard fertilisation tables were used for all ALT project trials from N0 to N3 applications. The detail of these fertilizer tables is given in annexe 1 for each year of planting. After that age, the fertilisation is monitored trial per trial through their nutritional status. The data were corrected from possible environmental and fertilisation effects through the network of repeated progenies (see Table 2 above).

The statistical analyses done to evaluate ancestor effects have been carried out with XLSTAT ®. The Pearson model of Factorial Analyse in main components has been selected.

On the commercial blocks, the annual sampling is carried out, as it serves as a steering tool for the recommendation of manure, and in the same manner, the annual analyses are also carried out on the experiments in order to monitor the effects of treatments on the palm nutrition.

The commercial fertilisation policy adopts a fixed fertilisation from N0 to N5. The same standard fertilisation table used for ALT project has been also used for all the commercial blocks. The data for 3- years -old coming from 63 commercial blocks planted in 9 different estates have been used or this study.

# RESULTS

## MINERAL NUTRITION IN AEK LOBA TIMUR GENETIC BLOC

### Mineral nutrition at 3 years old

Table 4 gives the general mean, the standard errors and the values exceeding deviation passing this standard error.

Table 4: General Mean and standard error at 3 years old

| | Nitrogen | Phosphorus | Potassium | Calcium | Magnesium |
|---|---|---|---|---|---|
| Mean | 2.943 | 0.167 | 0.904 | 1.149 | 0.230 |
| STDev | 0.086 | 0.004 | 0.121 | 0.149 | 0.034 |
| m-s | 2.858 | 0.163 | 0.782 | 0.999 | 0.196 |
| m+s | 3.029 | 0.172 | 1.025 | 1.298 | 0.265 |

Tables 5 and 6 summarize the A group families results at 3- years -old at the ALT project and in commercial blocs. Different colours underline the average position of the families in their group:

- Above m + s: Dark green
- From m + s to m: Pale green
- From m to m – s: Pale yellow
- Below m – s: Yellow

Table 5: 3- years -old values for the A Group origins at the ALT project

| Sub-Group | A origin | N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| AN x Socfin | (TNR115xLM630D)I | 3.054 | 0.166 | 1.021 | 1.069 | 0.191 |
| Socfindo | BB126DxBB150D | 2.877 | 0.173 | 1.166 | 0.910 | 0.207 |
| Socfindo | BB177DxBB129D | 2.892 | 0.167 | 1.062 | 0.986 | 0.190 |
| Socfindo | BB206Dselfed | 2.862 | 0.169 | 1.101 | 0.966 | 0.205 |
| Dabou | (DA5DxDA3D)selfed | 2.966 | 0.169 | 0.855 | 1.177 | 0.257 |
| Dabou | DA 10 D | 2.964 | 0.169 | 0.989 | 1.125 | 0.194 |
| Dabou | DA10DxDA3D | 2.983 | 0.167 | 0.892 | 1.100 | 0.217 |
| Dabou | DA10DxDA115D | 2.957 | 0.167 | 0.865 | 1.228 | 0.236 |
| Dabou | DA 115 D | 3.035 | 0.168 | 0.789 | 1.342 | 0.242 |
| Dabou | DA115D II | 2.901 | 0.165 | 0.866 | 1.333 | 0.215 |
| Dabou | DA115Dselfed | 2.994 | 0.168 | 0.813 | 1.276 | 0.238 |
| Dabou | DA115DxDA3D | 3.002 | 0.167 | 0.773 | 1.240 | 0.233 |
| Socfin x Dabou | LM269DxDA115D | 2.950 | 0.169 | 0.850 | 1.257 | 0.212 |
| Socfin x Dabou | LM269DxDA128D | 2.919 | 0.166 | 0.900 | 1.070 | 0.270 |
| Dabou | DA300DxDA128D | 2.891 | 0.168 | 0.888 | 1.097 | 0.221 |
| Dabou | DA551DxDA767D | 2.918 | 0.163 | 0.757 | 1.244 | 0.277 |
| Socfin | LM404Dselfed | 2.869 | 0.166 | 0.916 | 1.097 | 0.233 |
| Socfin x Dabou | LM404DxDA10D | 2.929 | 0.165 | 0.914 | 1.125 | 0.215 |
| Socfin x Dabou | LM404DxDA3D | 2.937 | 0.169 | 0.925 | 1.072 | 0.203 |

Table 6: 3- years -old values for the A group Ancestor families in the commercial blocks

| Sub-Group | A origin | N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| Dabou | DA115D x (DA5D x DA3D) | 2.83 | 0.178 | 1.12 | 0.880 | 0.265 |
| Dabou | DA115Dselfed | 2.88 | 0.174 | 0.98 | 0.847 | 0.305 |
| Dabou | DA5D x DA3D | 2.89 | 0.176 | 1.02 | 0.808 | 0.291 |
| Socfin x Dabou | (DA5D x DA3D) x (LM404DxDA10D) | 2.89 | 0.174 | 0.99 | 0.823 | 0.281 |
| Socfin x Dabou | LM404D x (DA5D x DA3D) | 2.81 | 0.178 | 0.97 | 1.045 | 0.250 |
| Socfin x Dabou | LM404D x DA10D | 2.87 | 0.175 | 1.03 | 0.915 | 0.285 |
| Socfin x Socfin | LM404D x LM270D | 2.91 | 0.190 | 1.09 | 0.765 | 0.345 |
| Socfindo | BB126DxBB150D | 2.84 | 0.182 | 1.10 | 0.890 | 0.275 |
| Socfindo | BB206Dselfed | 3.02 | 0.186 | 1.06 | 0.981 | 0.276 |
| | General Mean | 2.88 | 0.179 | 1.04 | 0.884 | 0.286 |
| | Standard Deviation | 0.06 | 0.006 | 0.06 | 0.087 | 0.027 |

The ancestor families that are not represented in the ALT project are highlighted in blue – green. Tables 7 and 8 summarize the B group families results at 3- years -old in the ALT project and in the commercial blocs.

Table 7: 3- years -old values for B Group origins in the ALT project

| Sub Group | B origin | N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| LM | LM 2 T | 2.992 | 0.168 | 0.909 | 1.212 | 0.213 |
| LM | LM2Tselfed | 2.967 | 0.166 | 0.888 | 1.176 | 0.212 |
| LM | (LM2T)II | 2.999 | 0.170 | 0.893 | 1.135 | 0.215 |
| LM | LM2TxLM10T | 3.025 | 0.169 | 0.854 | 1.181 | 0.219 |
| LM | LM2TxLM5T | 2.986 | 0.167 | 0.900 | 1.176 | 0.215 |
| LM | LM5TxLM2T | 2.866 | 0.167 | 0.928 | 1.122 | 0.207 |
| LM | LM5Tselfed | 2.929 | 0.166 | 0.799 | 1.255 | 0.234 |
| LM | LM5TxLM311P | 2.915 | 0.164 | 0.845 | 1.227 | 0.265 |
| LM | LM5TxLM10T | 2.953 | 0.168 | 0.833 | 1.155 | 0.225 |
| LM | LM10Tselfed | 2.988 | 0.167 | 0.840 | 1.250 | 0.229 |
| LM x SI | (LM2TxSI10T)I | 2.965 | 0.172 | 0.970 | 1.065 | 0.224 |
| SOCFINDO | BB85Tselfed | 2.902 | 0.174 | 1.161 | 0.900 | 0.227 |
| SOCFINDO | BB85TxBB20P | 2.860 | 0.172 | 1.215 | 0.864 | 0.201 |
| YA | LM238TxLM511P | 2.912 | 0.166 | 0.904 | 1.069 | 0.259 |
| YA | LM718TxLM238T | 2.893 | 0.171 | 1.044 | 0.980 | 0.241 |
| YA | PO 4157 T | 2.788 | 0.164 | 0.956 | 1.055 | 0.198 |
| NIFOR | PO1879TxPO1876T | 2.861 | 0.170 | 1.191 | 0.947 | 0.193 |
| Other | PO 3660 P | 2.778 | 0.153 | 0.935 | 1.057 | 0.287 |
| Other | BB 106 T | 2.687 | 0.163 | 1.075 | 0.894 | 0.163 |
| Other | FR10 | 2.851 | 0.163 | 0.739 | 1.348 | 0.257 |
| Other | ?xLM9T | 2.876 | 0.166 | 0.839 | 1.074 | 0.232 |
| Other | FR9 | 2.891 | 0.165 | 0.836 | 1.302 | 0.259 |
| Other | LM426Tselfed | 2.944 | 0.168 | 0.950 | 1.219 | 0.231 |
| Other | LM2TxLM231T | 3.044 | 0.175 | 0.817 | 1.250 | 0.309 |

Table 8: 3- years -old values for commercial planting material

| Sub-Group | B origin | N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| La Mé | LM2T selfed | 2.88 | 0.175 | 1.00 | 0.848 | 0.285 |
| La Mé | LM5T selfed | 2.91 | 0.179 | 0.99 | 0.841 | 0.286 |
| La Mé | LM5T x LM311P | 3.01 | 0.176 | 0.88 | 0.940 | 0.295 |
| Yangambi | LM718T selfed | 3.02 | 0.186 | 1.06 | 0.981 | 0.276 |
| Yangambi | LM718T x LM238T | 2.88 | 0.187 | 1.09 | 0.807 | 0.322 |
| | General Mean | 2.94 | 0.181 | 1.01 | 0.883 | 0.293 |
| | Standard Deviation | 0.064 | 0.006 | 0.082 | 0.073 | 0.018 |

LM718T selfed is not represented in ALT project series. This selfing is just represented in the project by the only PO4157T. This palm cannot be considered as representative of the selfing.

**Mineral nutrition at 5 to 7- years -old**

Tables 9 to 11 deliver equivalent information for 5 to 7- years -old results.

Table 9: General means and standard error at 5 to 7- years –old in ALT project

| | Nitrogen | Phosphorus | Potassium | Calcium | Magnesium | Chlorine | Boron |
|---|---|---|---|---|---|---|---|
| Mean | 2.731 | 0.164 | 0.984 | 0.890 | 0.182 | 0.691 | 15.0 |
| STDev | 0.085 | 0.004 | 0.105 | 0.098 | 0.028 | 0.058 | 1.592 |
| m-s | 2.645 | 0.160 | 0.879 | 0.792 | 0.155 | 0.633 | 13.435 |
| m+s | 2.816 | 0.168 | 1.089 | 0.988 | 0.210 | 0.748 | 16.619 |

Table 10: 5 to 7- years -old value for the A Group origins in ALT project

| Sub-Group | A origin | N | P | K | Ca | Mg | Cl | B |
|---|---|---|---|---|---|---|---|---|
| AN x Socfin | (TNR115xLM630D)I | 2.813 | 0.163 | 1.008 | 0.881 | 0.161 | 0.748 | 14.053 |
| Socfindo | BB126DxBB150D | 2.633 | 0.166 | 1.146 | 0.739 | 0.171 | 0.693 | 13.225 |
| Socfindo | BB177DxBB129D | 2.668 | 0.162 | 1.105 | 0.794 | 0.151 | 0.672 | 12.398 |
| Socfindo | BB206Dselfed | 2.660 | 0.165 | 1.165 | 0.782 | 0.160 | 0.706 | 12.916 |
| Dabou | (DA5DxDA3D)selfed | 2.744 | 0.165 | 1.008 | 0.910 | 0.194 | 0.683 | 15.483 |
| Dabou | DA 10 D | 2.776 | 0.163 | 1.074 | 0.858 | 0.162 | 0.697 | 14.4 |
| Dabou | DA10DxDA3D | 2.765 | 0.163 | 0.951 | 0.906 | 0.168 | 0.640 | 14.708 |
| Dabou | DA10DxDA115D | 2.745 | 0.162 | 0.950 | 0.936 | 0.182 | 0.682 | 15.623 |
| Dabou | DA 115 D | 2.828 | 0.163 | 0.915 | 1.019 | 0.195 | 0.742 | 16.6 |
| Dabou | DA115D II | 2.748 | 0.160 | 0.973 | 0.918 | 0.171 | 0.728 | 15.392 |
| Dabou | DA115Dselfed | 2.800 | 0.164 | 0.883 | 0.983 | 0.195 | 0.719 | 16.487 |
| Dabou | DA115DxDA3D | 2.711 | 0.161 | 0.867 | 0.979 | 0.172 | 0.662 | 15.754 |
| Socfin x Dabou | LM269DxDA115D | 2.751 | 0.164 | 0.951 | 0.921 | 0.180 | 0.670 | 15.921 |
| Socfin x Dabou | LM269DxDA128D | 2.648 | 0.161 | 0.942 | 0.903 | 0.207 | 0.618 | 15.540 |
| Dabou | DA300DxDA128D | 2.690 | 0.164 | 0.989 | 0.858 | 0.189 | 0.730 | 15.178 |
| Dabou | DA551DxDA767D | 2.737 | 0.157 | 0.714 | 1.032 | 0.260 | 0.672 | 17.248 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Socfin | LM404Dselfed | 2.685 | 0.166 | 0.950 | 0.902 | 0.186 | 0.672 | 15.157 |
| Socfin x Dabou | LM404DxDA10D | 2.754 | 0.166 | 0.970 | 0.912 | 0.181 | 0.683 | 15.825 |
| Socfin x Dabou | LM404DxDA3D | 2.752 | 0.168 | 0.967 | 0.879 | 0.164 | 0.674 | 14.662 |

Table 11: 5 to 7- years -old value for B Group origins in ALT project

| Sub Group | B origin | N | P | K | Ca | Mg | Cl | B |
|---|---|---|---|---|---|---|---|---|
| LM | LM 2 T | 2.797 | 0.163 | 1.011 | 0.922 | 0.175 | 0.715 | 15.3 |
| LM | LM2Tselfed | 2.773 | 0.164 | 0.973 | 0.898 | 0.170 | 0.710 | 15.329 |
| LM | (LM2T)II | 2.789 | 0.164 | 0.998 | 0.866 | 0.173 | 0.691 | 15.288 |
| LM | LM2TxLM10T | 2.773 | 0.164 | 0.937 | 0.933 | 0.170 | 0.686 | 15.536 |
| LM | LM2TxLM5T | 2.776 | 0.163 | 0.975 | 0.917 | 0.174 | 0.699 | 15.172 |
| LM | LM5TxLM2T | 2.726 | 0.167 | 1.048 | 0.881 | 0.151 | 0.756 | 14.138 |
| LM | LM5Tselfed | 2.730 | 0.164 | 0.886 | 0.982 | 0.187 | 0.705 | 16.505 |
| LM | LM5TxLM311P | 2.767 | 0.167 | 0.924 | 0.970 | 0.215 | 0.688 | 16.891 |
| LM | LM5TxLM10T | 2.741 | 0.164 | 0.915 | 0.915 | 0.182 | 0.713 | 14.938 |
| LM | LM10Tselfed | 2.792 | 0.164 | 0.936 | 0.973 | 0.171 | 0.696 | 15.702 |
| LM x SI | (LM2TxSI10T)I | 2.753 | 0.166 | 1.002 | 0.841 | 0.195 | 0.673 | 14.227 |
| SOCFINDO | BB85Tselfed | 2.630 | 0.167 | 1.136 | 0.725 | 0.183 | 0.680 | 13.961 |
| SOCFINDO | BB85TxBB20P | 2.619 | 0.166 | 1.216 | 0.706 | 0.172 | 0.722 | 13.820 |
| YA | LM238TxLM511P | 2.685 | 0.161 | 0.904 | 0.911 | 0.222 | 0.629 | 14.575 |
| YA | LM718TxLM238T | 2.636 | 0.164 | 1.040 | 0.826 | 0.195 | 0.664 | 13.852 |
| YA | PO 4157 T | 2.574 | 0.162 | 0.987 | 0.909 | 0.182 | 0.699 | 14.1 |
| NIFOR | PO1879TxPO1876T | 2.589 | 0.161 | 1.228 | 0.783 | 0.143 | 0.614 | 12.619 |
| Other | PO 3660 P | 2.486 | 0.150 | 1.055 | 0.804 | 0.185 | 0.593 | 13.7 |
| Other | BB 106 T | 2.587 | 0.164 | 1.097 | 0.737 | 0.135 | 0.704 | 12.4 |
| Other | FR10 | 2.712 | 0.161 | 0.894 | 0.947 | 0.225 | 0.730 | 15.607 |
| Other | ?xLM9T | 2.677 | 0.160 | 0.935 | 0.833 | 0.190 | 0.722 | 14.317 |
| Other | FR9 | 2.638 | 0.159 | 0.919 | 1.003 | 0.213 | 0.640 | 16.368 |
| Other | LM426Tselfed | 2.736 | 0.162 | 0.979 | 0.932 | 0.182 | 0.679 | 14.106 |
| Other | LM2TxLM231T | 2.716 | 0.165 | 0.933 | 0.988 | 0.229 | 0.673 | 16.359 |

## DISCUSSION

### MINERAL NUTRITION

As explained above, all the progenies planted in the ALT project received a fixed fertilisation. The possible environmental fluctuations as the soils fertility and the few differences in the fertilizer tables are stabilized through the corrections done with the repeated progenies. In this discussion, we do not include the illegitimate origins detected in B group.

In the commercial blocks, the nutrient content general means for both the group origins appear higher for the phosphorus, the potassium and the magnesium, even or lower in nitrogen but very lower in calcium compared to ALT project. It is to be noted that the ALT project is established on very calcic soils, which can explain the observed differences.

At 3- years -old, there is any A or B group origin showing excess in the phosphorus nutrition at the ALT project following the nitrogen – phosphorus balance commonly accepted (Tampubolon et *al*, 1990). Some of them present a strong phosphorus deficiency (Figures 1 and 2, next page):

For A Group origins: all DA115D origins except LM269D x DA115D, LM404D x DA10D, DA551D x DA767D and TNR115 x LM630D.
For B Group origins: nearly all La Mé group is borderline of Deficiency 2 level. Two Yangambi origins are very low: PO4157T (from LM718T selfed) and LM238T x LM511P. BB85T selfed is borderline of an excess of phosphorus leaf content.

Because of their better nutritional level in phosphorus, the situation is different in the commercial blocks. The N/P equilibrium is quite well balanced for the both groups of origins (Fig 2 and 3). Many of them even show a phosphorus excess. However, it is observed that the rank classifying the origins show similarities. For instance, in the A group, BB206D self and BB126D x BB150D are amongst the highest, and DA115D or LM404D x DA10D amongst the lowest (Fig 2) which is also observed in the ALT project on Fig 1.

Same similarities in the B group, where LM718T x LM238T is recorded in a better position compared to LM2T and LM5T x LM311P on Fig 4 are also ranked in the same order on Fig 2.

The Total Leaf Cation content and the nitrogen balance (Figures 5 and 6), is explored according the relationship proposed by Foster (2003). Many A Group origins are in a borderline situation. Note that TNR115 x LM630D presents an excessive high nitrogen leaf content and many families based on DA115D are under the optimum N. However, this last figure does not appear clearly in commercial blocs (Figure 7). The same observation could be delivered for the B Group origins: many out of them are in a borderline position except for LM5T Selfed and LM5T x LM311P (Figure 6). In commercial estates, LM5T x LM311P is in opposite position (Figure 8).

The calcium and the magnesium cation balance display a particular disequilibrium in general (detailed data in annexe). The Magnesium balance is generally recorded below 21%. It seems very specific to the Aek Loba Estate environment, when compared to the commercial blocs where Mg/TLC is currently always above 21% as shown in annex. Some origins present a notable excess in calcium (balance above 60%): that is concerning all the DA115D based origins from the A group and LM5T selfed or LM10T selfed for the B group. It appears that the family behavior could be specific to the location as noticed again, when the ALT project values are compared to the results from the commercial blocs.

At 5 to 7- years -old (Figures 9 and 10), the nitrogen – phosphorus balance appears improved in the ALT project. But for the both groups of origin, some families are still in Deficiency 2. For the A Group, are concerned DA115D itself, DA115D II, DA10D x DA115D, DA10D itself, DA551D x DA767D and TNR115 x LM630D. From the B group, LM2T itself and LM238T x LM511P present this strong phosphorus deficiency. BB85T selfed and BB85T x BB20P show correct nitrogen – phosphorus nutrition.

Concerning the nitrogen – Total Leaf Cation balance, the equilibriums seem slightly improved particularly for DA115D derived origins (Figure 11) in the A group origins. TNR115 x LM630D is still presenting an excess in nitrogen. In the B group origin (Figure 12), the families appear organized within two separate areas: the origins belonging to Yangambi or related families characterized by a relatively too low nitrogen content compared to their Total Leaf Cation in one hand. In other hand, LM2T and LM10T deriving origins show higher nitrogen than expected. Specific mention should be done for LM5T selfed and LM5T x LM311P that are presenting lower nitrogen contents than expected.

The calcium balance is decreasing for the A group origins from 56,7% to 52,9%; but in favour of the potassium balance only that grow from 23,6 to 29,5%. The magnesium balance is still miserable. The same figure is recorded in similar evolution for the B group origins.

Figure 1: Nitrogen - Phosphorus balance for the A group origins at 3- years -old (ALT project)

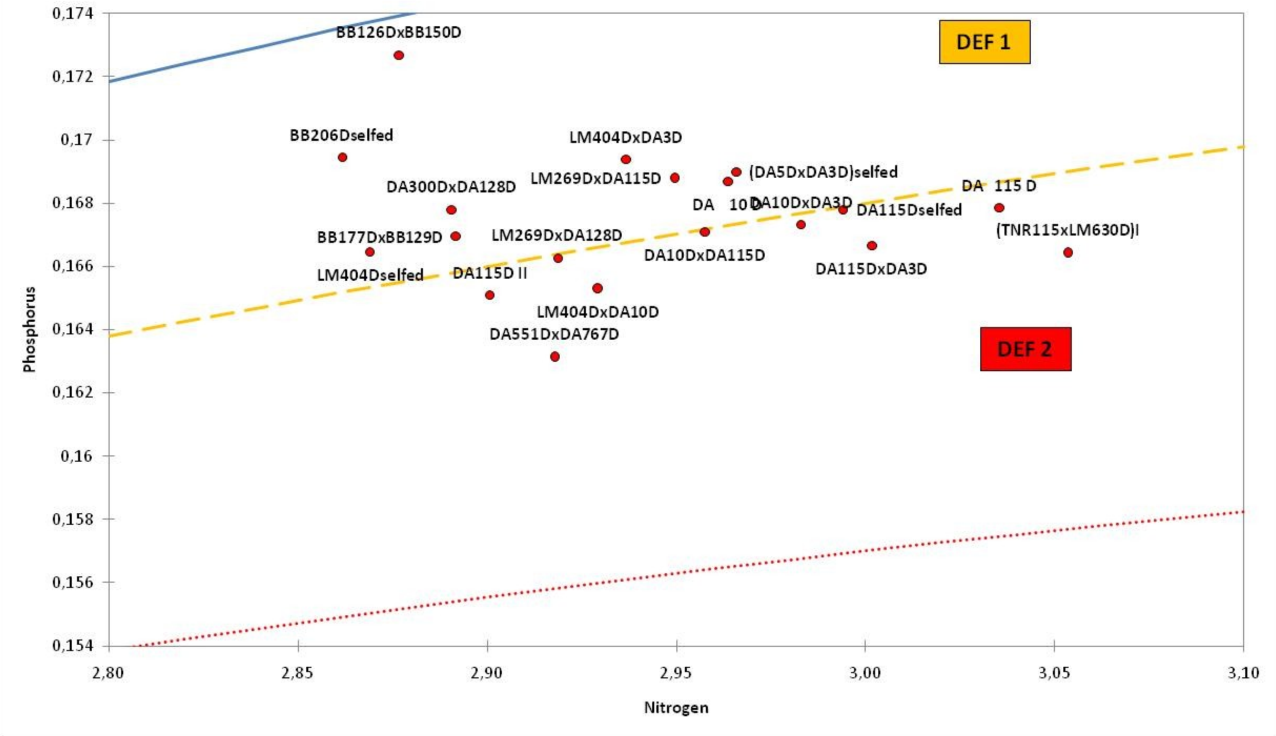
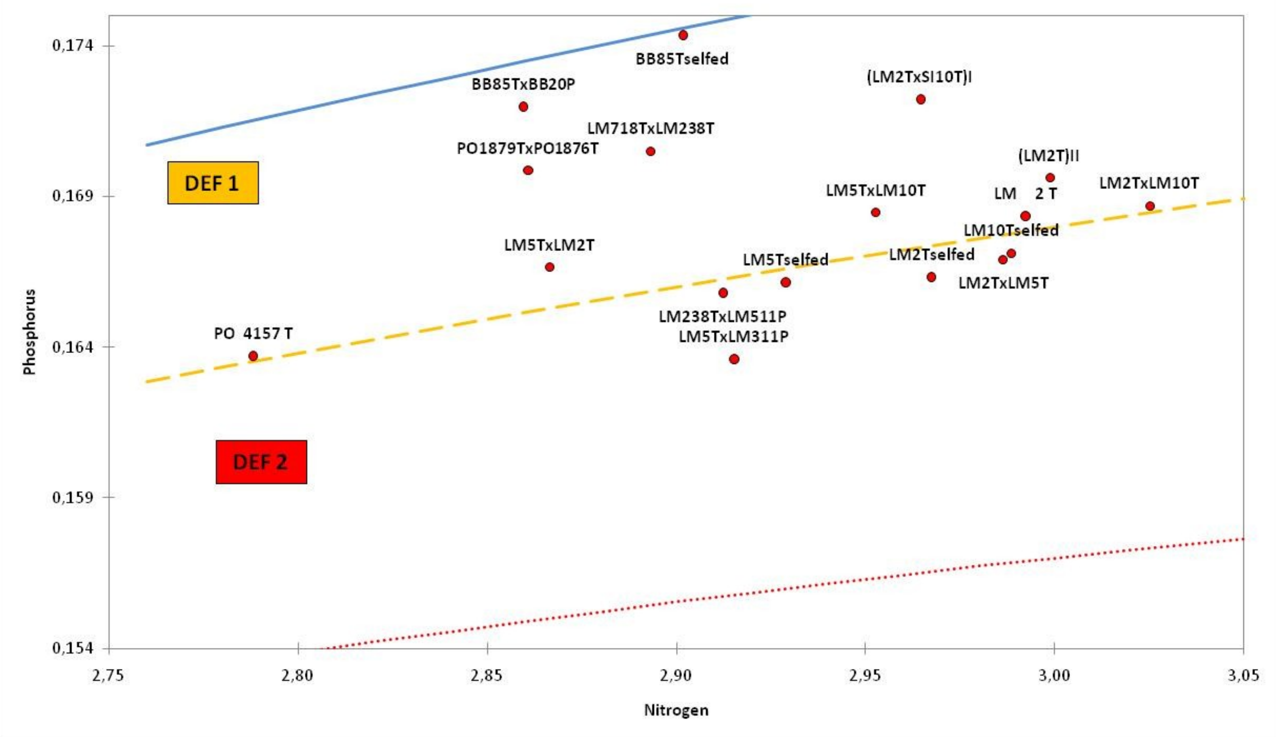



Figure 2: Nitrogen - Phosphorus balance for the B group origins at 3- years -old (ALT project)



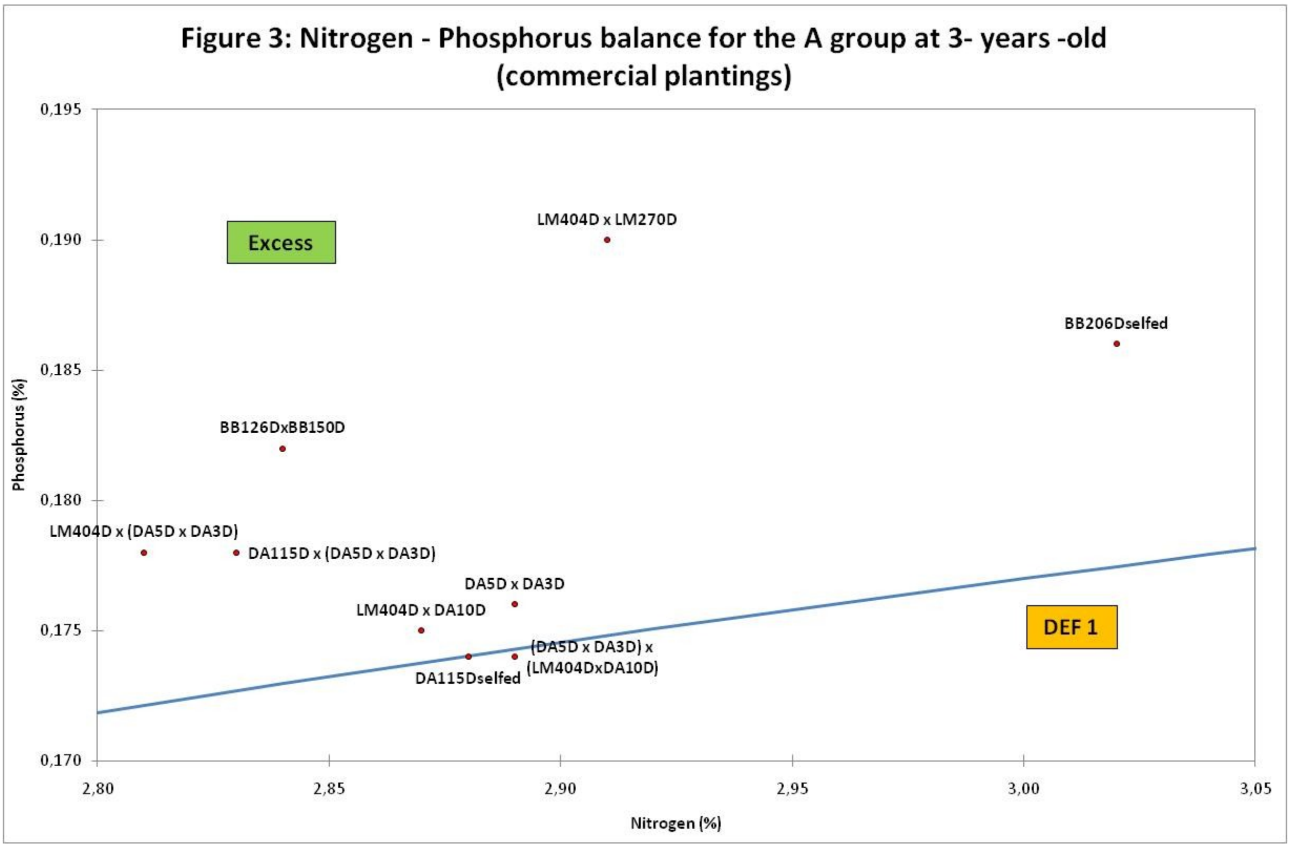


Figure 3: Nitrogen - Phosphorus balance for the A group at 3- years -old (commercial plantings)
0,195
0,190
0,185
0,180
0,175
0,170
Phosphorus (%)
Excess
LM404D x LM270D
BB206Dselfed
BB126DxBB150D
LM404D x (DA5D x DA3D)
DA115D x (DA5D x DA3D)
DA5D x DA3D
LM404D x DA10D
DEF 1
(DA5D x DA3D) x (LM404DxDA10D)
DA115Dselfed
2,80
2,85
2,90
2,95
3,00
3,05
Nitrogen (%)

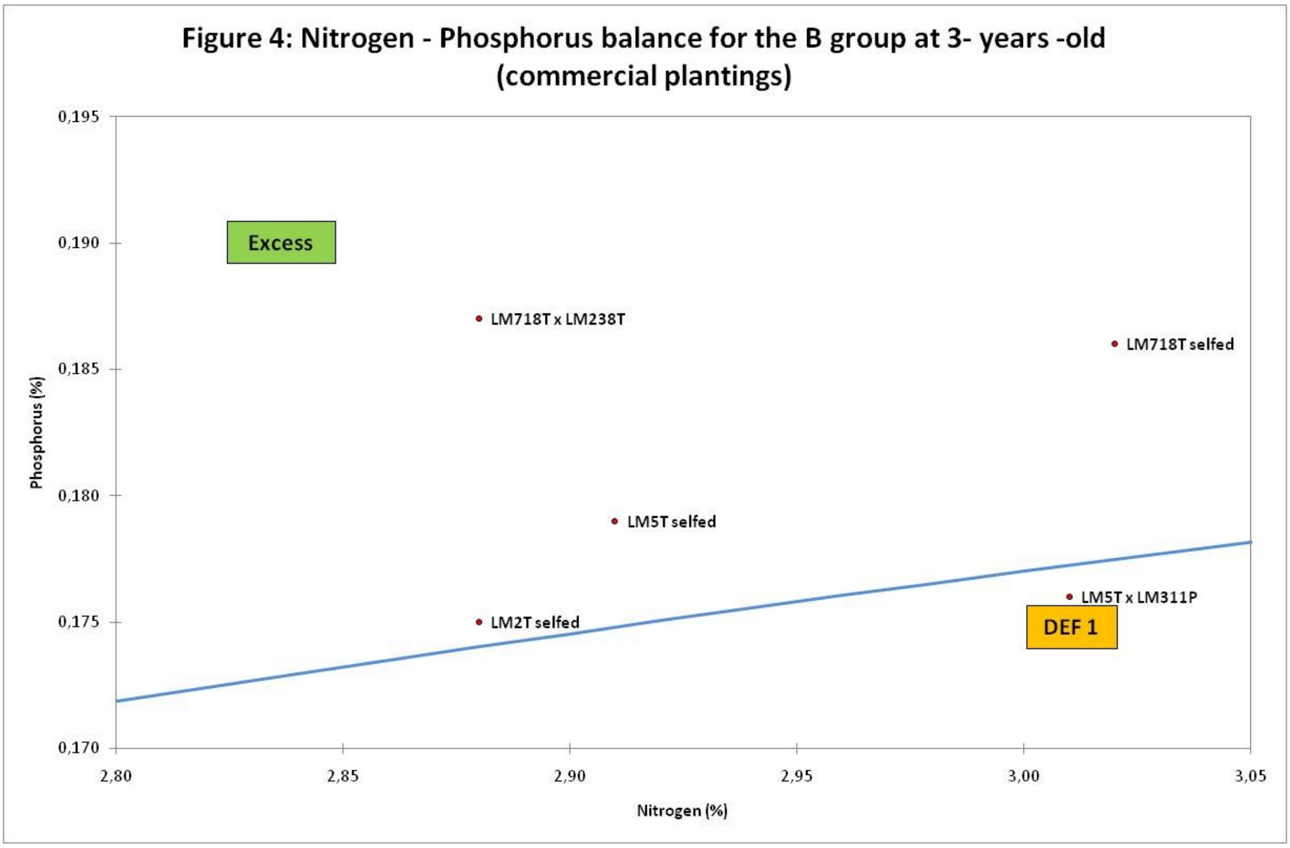


Figure 4: Nitrogen - Phosphorus balance for the B group at 3- years -old (commercial plantings)
0,195
0,190
0,185
0,180
0,175
0,170
Phosphorus (%)
Excess
LM718T x LM238T
LM718T selfed
LM5T selfed
LM5T x LM311P
LM2T selfed
DEF 1
2,80
2,85
2,90
2,95
3,00
3,05
Nitrogen (%)

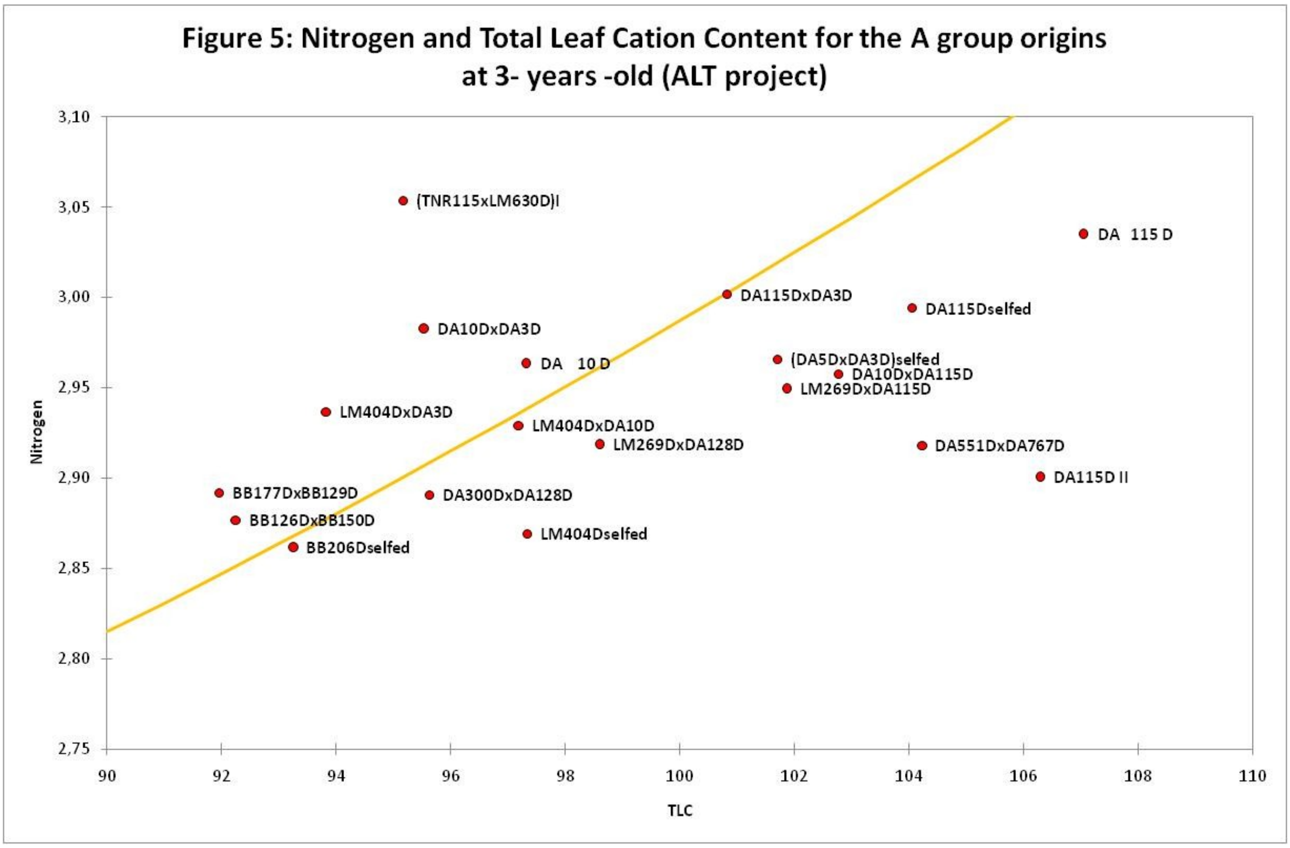


Figure 5: Nitrogen and Total Leaf Cation Content for the A group origins
at 3- years -old (ALT project)
Nitrogen
TLC
3,10
3,05
3,00
2,95
2,90
2,85
2,80
2,75
90
92
94
96
98
100
102
104
106
108
110
(TNR115xLM630D)I
DA 115 D
DA115DxDA3D
DA115Dselfed
DA10DxDA3D
DA 10 D
(DA5DxDA3D)selfed
DA10DxDA115D
LM269DxDA115D
LM404DxDA3D
LM404DxDA10D
LM269DxDA128D
DA551DxDA767D
DA115D II
BB177DxBB129D
DA300DxDA128D
BB126DxBB150D
LM404Dselfed
BB206Dselfed

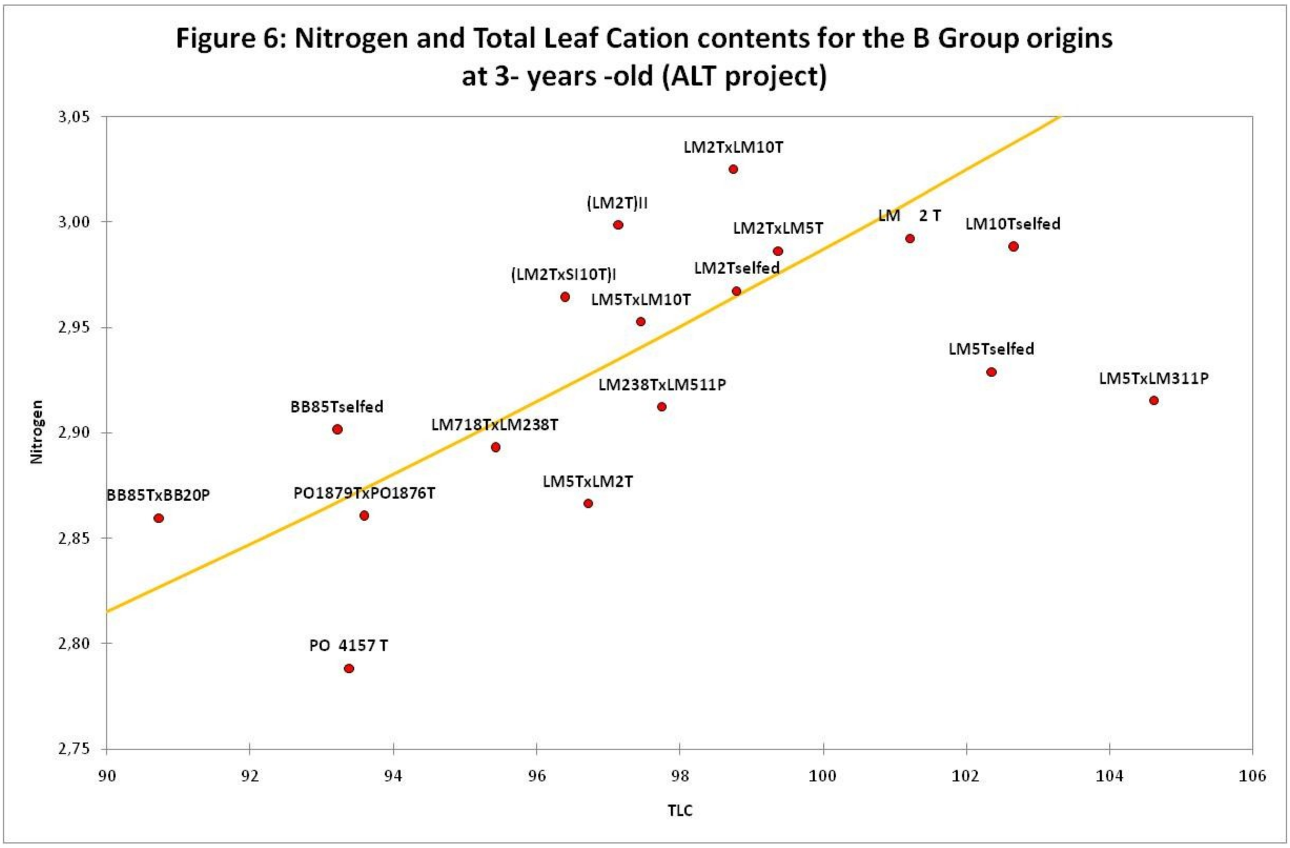


Figure 6: Nitrogen and Total Leaf Cation contents for the B Group origins
at 3- years -old (ALT project)
Nitrogen
TLC
3,05
3,00
2,95
2,90
2,85
2,80
2,75
90
92
94
96
98
100
102
104
106
LM2TxLM10T
(LM2T)II
LM2TxLM5T
LM 2 T
LM10Tselfed
LM2Tselfed
(LM2TxSI10T)I
LM5TxLM10T
LM5Tselfed
LM5TxLM311P
LM238TxLM511P
BB85Tselfed
LM718TxLM238T
LM5TxLM2T
BB85TxBB20P
PO1879TxPO1876T
PO 4157 T

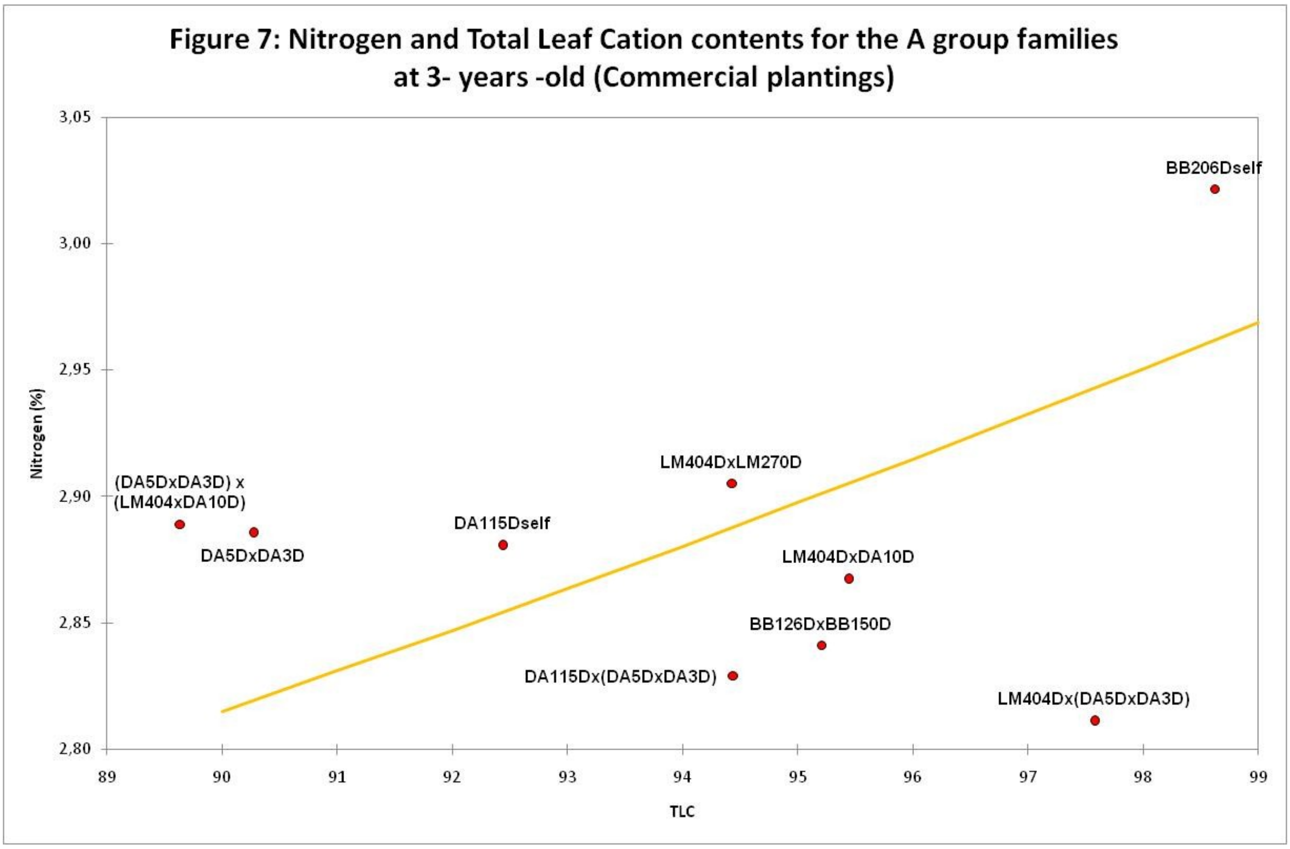


Figure 7: Nitrogen and Total Leaf Cation contents for the A group families
at 3- years -old (Commercial plantings)
Nitrogen (%)
TLC
3,05
3,00
2,95
2,90
2,85
2,80
89
90
91
92
93
94
95
96
97
98
99
BB206Dself
LM404DxLM270D
(DA5DxDA3D) x
(LM404xDA10D)
DA5DxDA3D
DA115Dself
LM404DxDA10D
BB126DxBB150D
DA115Dx(DA5DxDA3D)
LM404Dx(DA5DxDA3D)

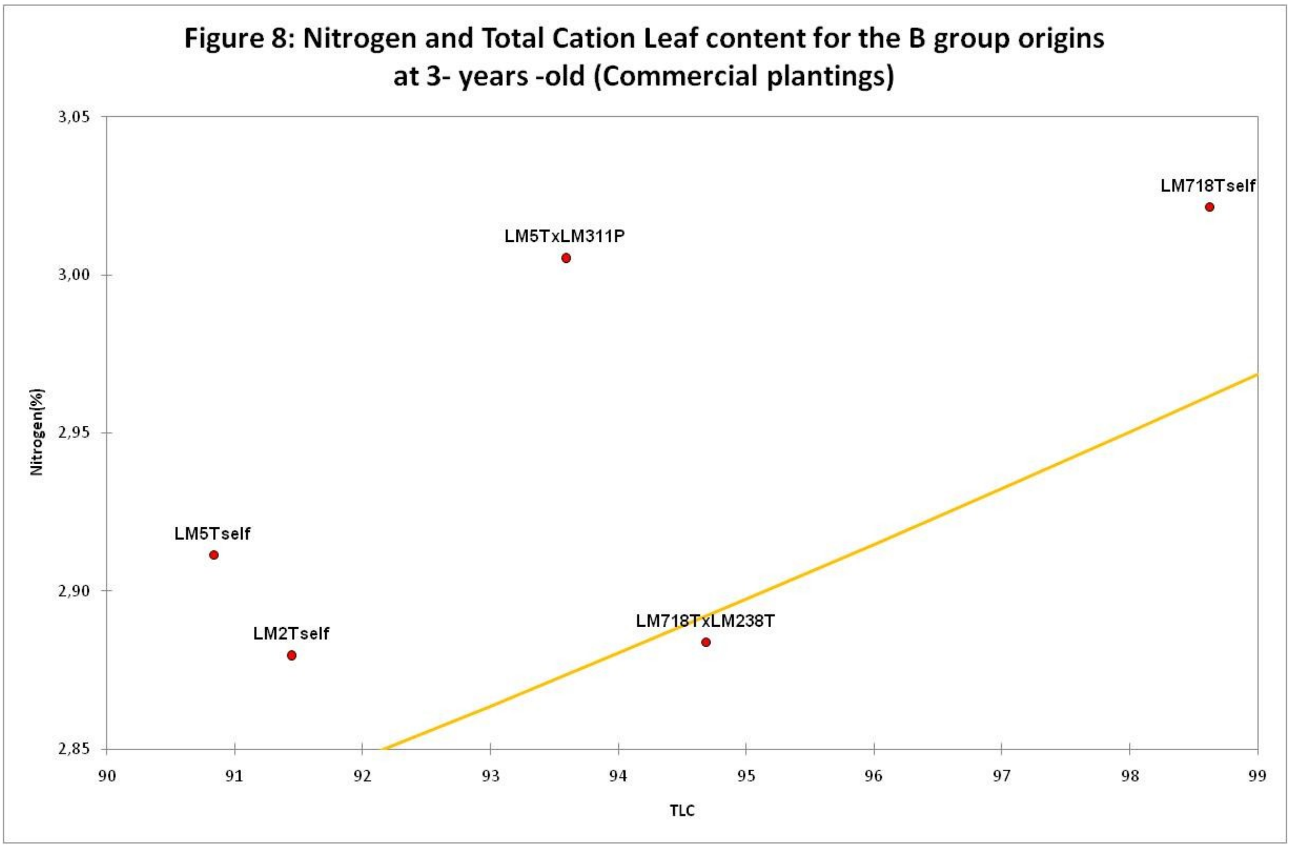



Figure 8: Nitrogen and Total Cation Leaf content for the B group origins
at 3- years -old (Commercial plantings)
Nitrogen(%)
TLC
3,05
3,00
2,95
2,90
2,85
90
91
92
93
94
95
96
97
98
99
LM718Tself
LM5TxLM311P
LM5Tself
LM2Tself
LM718TxLM238T

Figure 9: Nitrogen - Phosphorus balance for the A group origins at 5 to 7- years -old (ALT project)

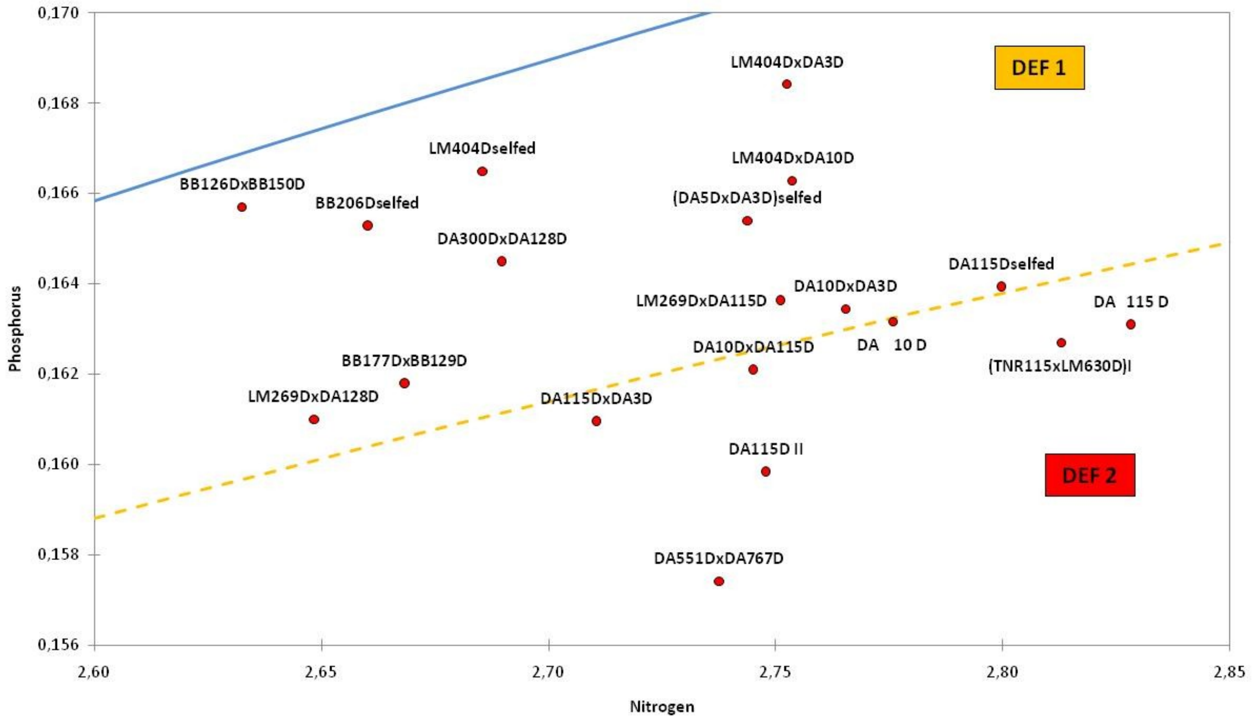
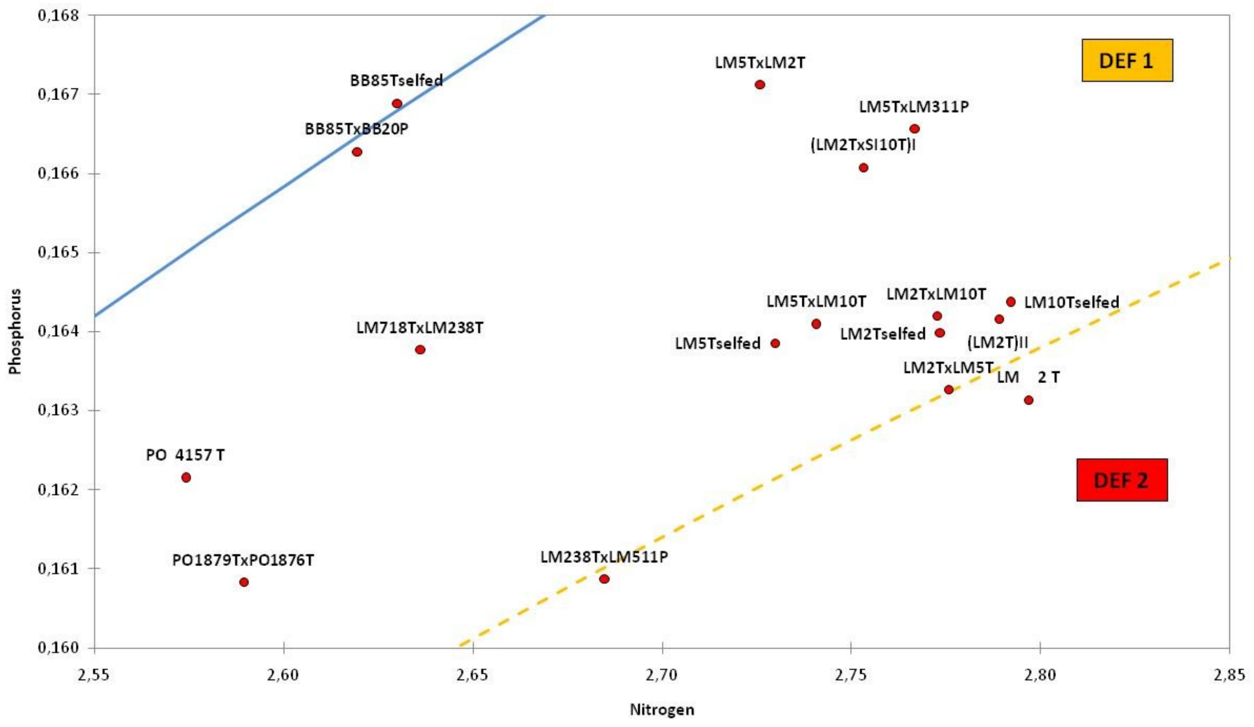



Figure 10: Nitrogen - Phosphorus balance for the B Group origins at 5 to 7- years -old (ALT project)



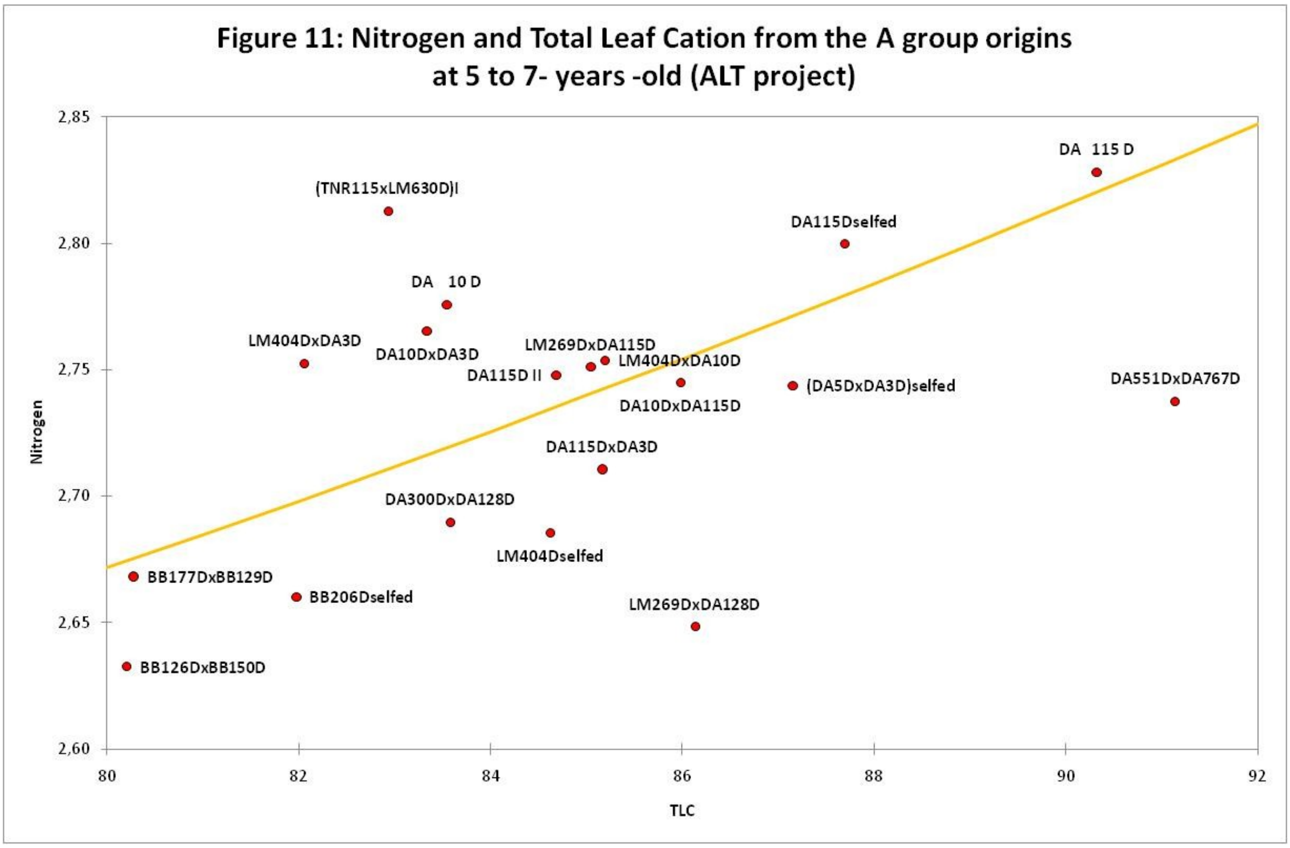


Figure 11: Nitrogen and Total Leaf Cation from the A group origins
at 5 to 7- years -old (ALT project)
Nitrogen
TLC
2,85
2,80
2,75
2,70
2,65
2,60
80
82
84
86
88
90
92
DA 115 D
(TNR115xLM630D)I
DA115Dselfed
DA 10 D
LM404DxDA3D
DA10DxDA3D
LM269DxDA115D
LM404DxDA10D
DA115D II
(DA5DxDA3D)selfed
DA551DxDA767D
DA10DxDA115D
DA115DxDA3D
DA300DxDA128D
LM404Dselfed
BB177DxBB129D
BB206Dselfed
LM269DxDA128D
BB126DxBB150D

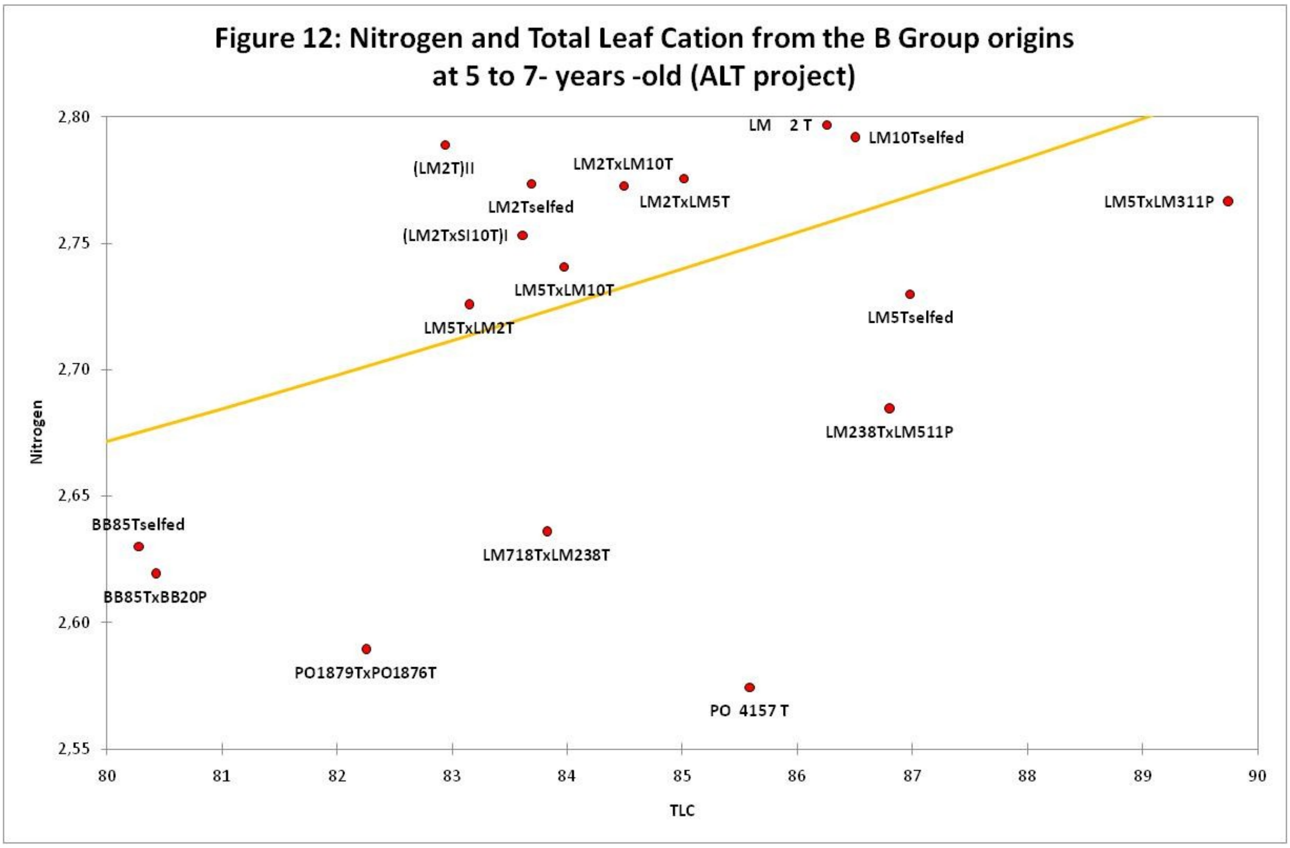


Figure 12: Nitrogen and Total Leaf Cation from the B Group origins
at 5 to 7- years -old (ALT project)
Nitrogen
TLC
2,80
2,75
2,70
2,65
2,60
2,55
80
81
82
83
84
85
86
87
88
89
90
LM 2 T
LM10Tselfed
(LM2T)II
LM2TxLM10T
LM2Tselfed
LM2TxLM5T
LM5TxLM311P
(LM2TxSI10T)I
LM5TxLM10T
LM5TxLM2T
LM5Tselfed
LM238TxLM511P
BB85Tselfed
LM718TxLM238T
BB85TxBB20P
PO1879TxPO1876T
PO 4157 T

**MINERAL NUTRITION X GENOTYPE INTERACTION**

In our comments on mineral nutrition, it appears obviously that some origins from both groups are presenting some "permanent" characteristics. Table 12 showing correlation for mineral leaf content at 3 years old and at 5 – 7 years old is confirming this fact.

Table 12: Correlation between Year 3 and adult stage

| | A Group | B Group |
|---|---|---|
| Nitrogen | 0,81 | 0,82 |
| Phosphorus | 0,64 | 0,74 |
| Potassium | 0,89 | 0,95 |
| Calcium | 0,87 | 0,94 |
| Magnesium | 0,88 | 0,84 |

.
This very highly significant relationship (r > ***) allows to study population structures in both the groups. For that matter, the following variables that seem the most characteristic are used:

- Nitrogen (%), K/TLC (%), Ca/TLC (%), Mg/TLC (%) and Chlorine (%)
- Chlorine is available only for 5 – 7 years old data.

For the A group of origins, all the families are studied at 3 and 5 to 7- years -old. For the B group origins, only the legitimate families are analyzed.

**Analyse of the A Group origin population**

Table 13 summarises the correlations between the variables and the axis at 3- years -old. F1 x F2 system covers 86.9% of observed variability.

Table 13: Correlations between variables and axis

| | F1 | F2 | F3 |
|---|---|---|---|
| Nitrogen | 0,697 | -0,425 | 0,578 |
| MG/TLC | 0,146 | 0,952 | 0,269 |
| CA/TLC | 0,945 | -0,126 | -0,303 |
| K/TLC | -0,942 | -0,293 | 0,166 |

At that age, it is interesting to notice that Ca/TLC and nitrogen vectors are very close together (Figure 13). Two populations could be easily isolated: DA115D and all its derived families (high Ca/TLC and nitrogen; low potassium) in blue circle and in opposite Socfindo originated families (High potassium; low Ca/TLC and nitrogen) in dashed orange circle. Three other families present interesting position: TNR115 x LM630D (very low Mg/TLC), and LM269D x DA128D and DA551D x DA767D in opposite (very high Mg/TLC).

Table 14 summarises correlations between variables and axis at 5 to 7- years -old. F1 x F2 system covers 83.1% of observed variability.

Figure 13: A Group families Biplot at 3- years -old at ALT project (F1 & F2 axis: 86,87 %)

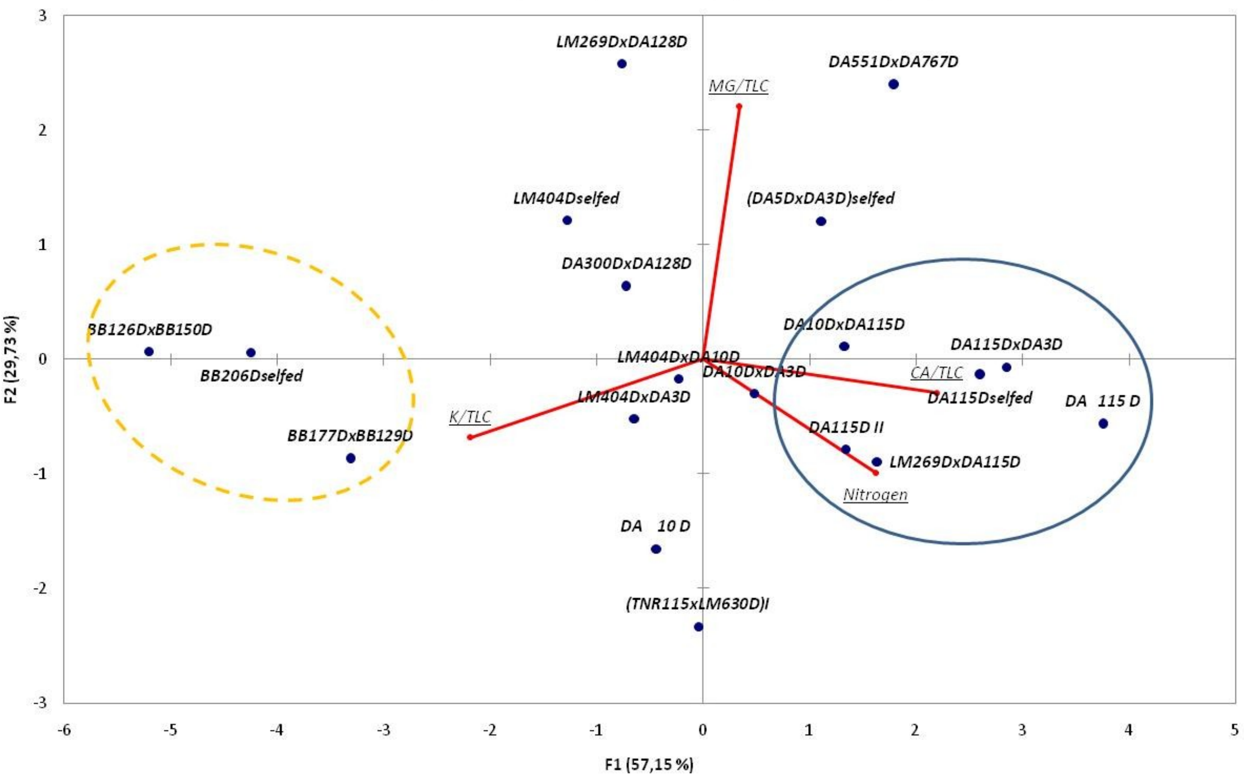



Figure 14: A Group families Biplot at 5 to7- years -old at ALT project (F1 & F2 axix : 83,13 %)

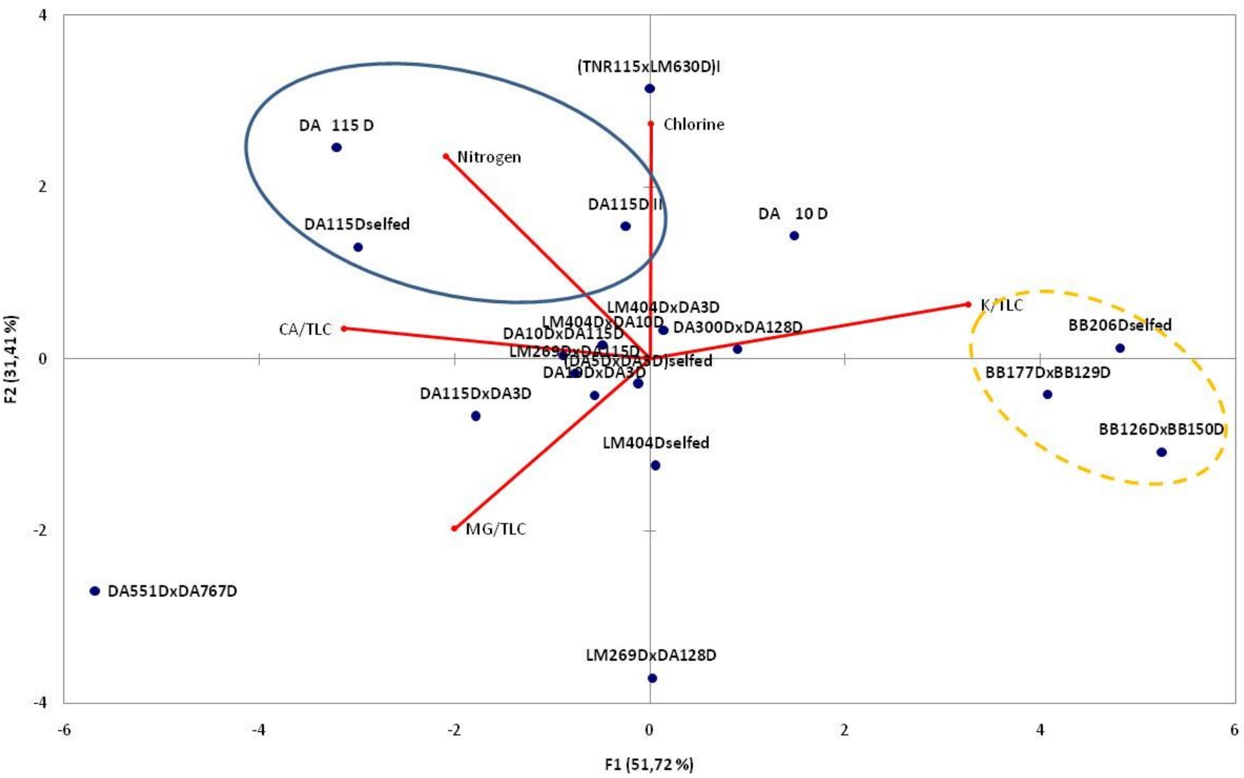


Table 14: Correlation between variables and axis at 5 - 7 years old

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| Nitrogen | -0.627 | 0.707 | -0.157 | 0.287 |
| MG/TLC | -0.599 | -0.592 | 0.521 | 0.141 |
| CA/TLC | -0.938 | 0.107 | -0.266 | -0.196 |
| K/TLC | 0.977 | 0.191 | -0.039 | 0.083 |
| Chlorine | 0.003 | 0.820 | 0.555 | -0.139 |

Introduction of the chlorine as new variable is reversing the direction of the other vectors (Figure 14). DA115D and its selfings are stably isolated (blue circle). The other DA115D based families are joining a larger Deli group in the centre of the graph. Socfindo Deli families are also fixed together along F2 positive extremity (orange dashed circle).

TNR115 x LM630D (very low Mg/TLC) maintains its position as LM269D x DA128D and DA551D x DA767D (very high Mg/TLC).

The case of DA115D and its selfing derivates versus Socfindo deli families is interesting to analyze: in fact, for DA115D, the nitrogen, the calcium and the chlorine are high and the potassium is low. But the potassium nutrient is delivered by a Potassium Chlorine application. It is possible to imagine that this genotype could absorb easily the chlorine cation which pulls the calcium with it. In reverse, Socfindo Deli families do not absorb too much the chlorine, then the calcium, allowing the potassium to enter massively in the leaflets.

Looking at the Socfindo commercial planting materials, it is possible to isolate three groups that may need specific nutritional management:

- K-N+Ca+: DA115D
- K+N-Ca-: BB206D, BB126DxBB150D and BB177DxBB129D
- Medium: DA5DxDA3D, DA10DxDA115D, DA115DxDA3D, DA300DxDA128D, LM404Dselfed, LM404DxDA10D and LM404DxDA3D

DA10DxDA115D and DA115DxDA3D should be considered as K-N+Ca+ at immature stage. In other hand, 3 families are very far from previous groups: TNR115 x LM630D at F1 positive extremity, LM269D x DA128D at F1 negative extremity and DA551D x DA767D in external part of negative F1-F2 quarter.

**Analyse of the B Group origin population**

Table 15 summarises the correlations between the variables and the axis at 3- years -old. F1 x F2 system covers 86.6% of observed variability.

At 3- years -old, the nitrogen and Ca/TLC vectors are very narrow as for the A group origins. The position of the different families is well regrouped for La Mé origins and not that for other ones. But, in average, it is possible to say that the La Mé origins belong to the positive F1 axe (N+Ca+) and the Yangambi / Nifor / Kuala Krapuh origins to the negative F1 axe (N-Ca-). It seems that the LM2T derived families are more Mg- and the LM5T derived families are more Mg+.

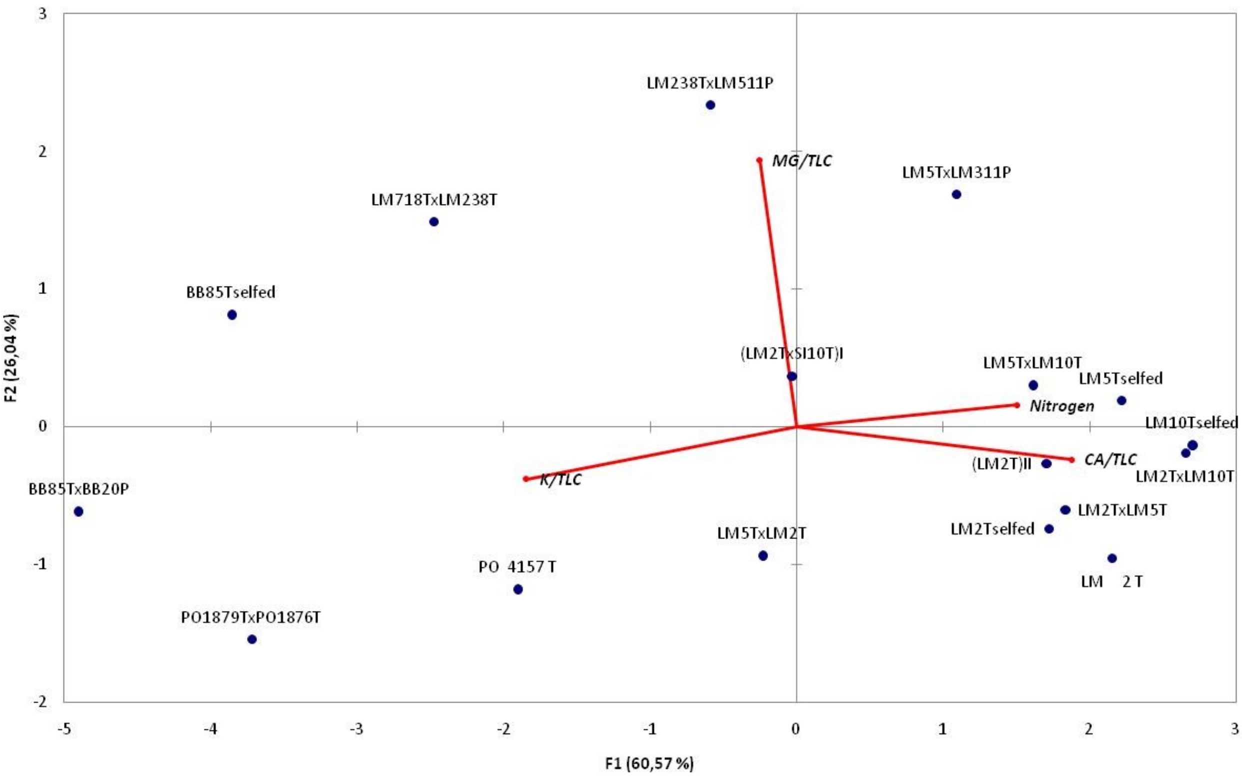


Figure 15: B group origins Biplot at 3- years -old at ALT project (F1 & F2 :axis: 86,61 %)

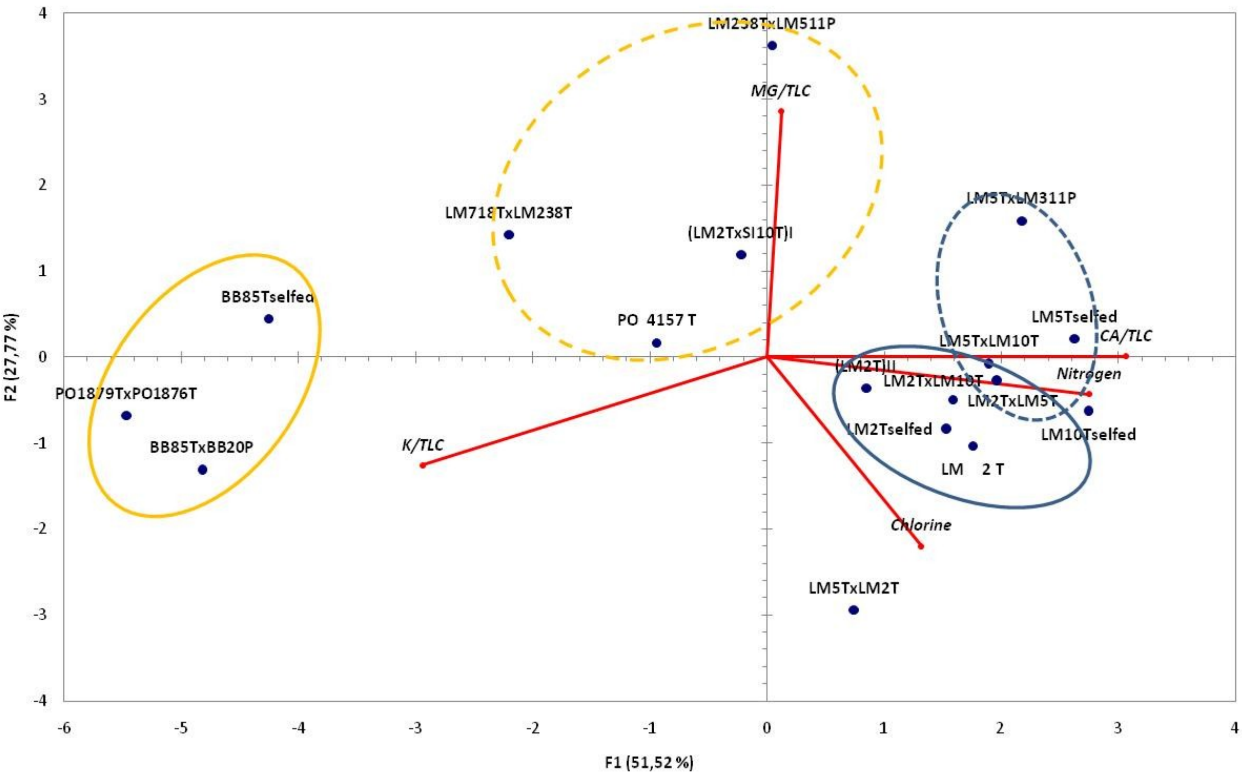


Figure 16: B group origins Biplot at 5 to7 -years -old at ALT project (F1 & F2 axis: 79,30 %)

Table 15: Correlation between variables and axis at 3 years old

| | F1 | F2 | F3 |
|---|---|---|---|
| Nitrogen | 0.770 | 0.080 | 0.633 |
| MG/TLC | -0.130 | 0.991 | -0.030 |
| CA/TLC | 0.961 | -0.122 | -0.250 |
| K/TLC | -0.944 | -0.195 | 0.266 |

At 5 to 7- years -old, the introduction of the chlorine as variable is precising this behaviour (Figure 16). The La Mé group is Cl+Ca+ and the Yangambi / Nifor / Kuala Krapuh origins are Cl-Ca-. It seems that some La Mé sub-groups, particularly LM2T and relatives, is functioning as DA115D and derived origins. Four groups of nutrition could be easily identified:

- Nifor / Kuala Krapuh families (orange circle): K+N-Ca-Cl-
- Yangambi families (dashed orange circle): K+ N-Ca-Cl-Mg+
- LM2T and deriving origins (blue circle): K-N+Ca+Cl+
- LM5T and deriving families (dashed blue circle): K-N+Ca+Cl+Mg+

In addition, LM10T and derived families are intermediate between LM2T and LM5T

## MINERAL NUTRITION AND CROP

The results from two specific trials (ALCP 61 and ALCP 62) are analyzed as explained previously. These two trials are the base of our knowledge to prove that mineral content critical level in the leaf could differ from one type of planting material to another (Jacquemard *et al*, 2002). These two experiments differ only by B Group pedigree: pollens used for ALCP 61 materials come from LM2T selfing and those for ALCP 62 come from LM311P itself. LM311P is deriving from LM2T by open pollination.

Despite these very narrow B group ancestors, the nutrient levels are quite contrasted (Table 16):

Table 16: Average mineral contents and crop for ALCP 61 and ALCP 62

| | | Leaf N | Leaf P | Leaf K | Leaf Ca | Leaf Mg | Leaf Cl |
|---|---|---|---|---|---|---|---|
| (DA5D x DA3D) x LM2T selfed | AL61 | 2,551 | 0,156 | 0,987 | 0,856 | 0,154 | 0,630 |
| (DA5D x DA3D) x LM311P | AL62 | 2,490 | 0,148 | 0,851 | 0,819 | 0,215 | 0,716 |
| | | Rachis P | Rachis K | | | | |
| (DA5D x DA3D) x LM2T selfed | AL61 | 0,076 | 2,34 | | | | |
| (DA5D x DA3D) x LM311P | AL62 | 0,061 | 2,14 | | | | |
| | | TLC | K/TLC | Mg/ TLC | Ca/TLC | | |
| (DA5D x DA3D) x LM2T selfed | AL61 | 80,6 | 31,4 | 15,7 | 52,9 | | |
| (DA5D x DA3D) x LM311P | AL62 | 80,3 | 27,2 | 22,0 | 50,8 | | |
| | | NB/p/yr | FFB / kg palm | AWB kg | CPO/ t / ha | | |
| (DA5D x DA3D) x LM2T selfed | AL61 | 12,4 | 208,2 | 17,0 | 6,84 | | |
| (DA5D x DA3D) x LM311P | AL62 | 10,1 | 191,4 | 19,2 | 6,42 | | |

LM311P is inducing much lower contents in leaf for nitrogen, phosphorus and potassium and higher level in magnesium and chlorine. In term of production, ALCP 61 is characterized by a larger number of smaller bunches per year.

Table 17 summarizes all the main statistical effects on the rachis or leaf mineral contents and the production data. The rachis and the leaf mineral contents are concerning 2008 campaign. Bunch number (BN), FFB (kg / tree), Average Bunch Weight (ABW; kg) and CPO (t / ha) are concerning 2006 / 2007 campaign that is the last recorded campaign. Significant differences are highlighted in bold and very significant in italic bold underlined police. The phosphorus application is depressing potassium contents in the leaf (ALCP 61 and ALCP 62) and in the rachis (ALCP 62). It increases the phosphorus contents in the leaf and in the rachis in both the experiments. It increases the crop (FFB, ABW and CPO) in ALCP 62.

The nitrogen application is increasing the nitrogen (ALCP 61 & 62) and the potassium leaf contents (ALCP 61). It is depressing the magnesium leaf contents in ALCP61.

The potassium application increases the potassium contents in leaf and rachis, but it depresses the magnesium leaf contents in ALCP 61 only.

Last, but not least, the magnesium application is increasing the magnesium leaf contents in ALCP 61 and crop (BN, FFB and CPO) in ALCP 62.

Table 17: rachis and leaf content, and production data main effects

| Trial | Effect | Niv | Rachis P 08 | Rachis K 08 | Leaf N 08 | Leaf P 08 | Leaf K 08 | Leaf Mg 08 | BN 06_07 | FFB 06_07 | ABW 06_07 | CPO 06_07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALCP 061 | Niv_P | 0 | **0.060** | 2.62 | 2.547 | **0.151** | ***1.041*** | 0.147 | 12.0 | 200.7 | 16.9 | 6.64 |
| | | 1 | **0.073** | 2.28 | 2.557 | **0.156** | ***0.976*** | 0.155 | 12.5 | 208.3 | 16.7 | 6.80 |
| | | 2 | **0.096** | 2.11 | 2.551 | **0.160** | ***0.942*** | 0.161 | 12.6 | 215.5 | 17.3 | 7.09 |
| | Niv_N | 0 | 0.083 | 2.38 | **2.494** | 0.154 | ***0.941*** | ***0.161*** | 12.5 | 210.4 | 17.0 | 6.96 |
| | | 1 | 0.074 | 2.22 | **2.571** | 0.156 | ***0.982*** | ***0.155*** | 12.4 | 206.5 | 16.9 | 6.80 |
| | | 2 | 0.072 | 2.41 | **2.590** | 0.156 | ***1.037*** | ***0.147*** | 12.3 | 207.6 | 16.9 | 6.76 |
| | Niv_K | 0 | 0.071 | **1.64** | 2.579 | 0.157 | **0.894** | ***0.178*** | 12.2 | 207.4 | 17.2 | 7.01 |
| | | 1 | 0.079 | **2.17** | 2.540 | 0.156 | **0.965** | ***0.155*** | 12.5 | 212.0 | 17.0 | 6.86 |
| | | 2 | 0.079 | **3.20** | 2.534 | 0.154 | **1.100** | ***0.130*** | 12.4 | 205.1 | 16.7 | 6.66 |
| | Niv_Mg | 1 | 0.079 | 2.37 | 2.529 | 0.155 | 1.001 | **0.134** | 12.3 | 205.9 | 16.9 | 6.76 |
| | | 2 | 0.074 | 2.30 | 2.574 | 0.157 | 0.972 | **0.175** | 12.4 | 210.4 | 17.1 | 6.92 |
| ALCP 062 | Niv_P | 0 | **0.053** | ***2.45*** | 2.485 | **0.142** | ***0.876*** | 0.216 | 9.4 | **173.0** | **18.6** | **5.84** |
| | | 1 | **0.060** | ***2.12*** | 2.473 | **0.147** | ***0.851*** | 0.215 | 10.3 | **194.4** | **19.0** | **6.48** |
| | | 2 | **0.069** | ***1.85*** | 2.514 | **0.154** | ***0.828*** | 0.213 | 10.6 | **207.0** | **19.9** | **6.93** |
| | Niv_N | 0 | 0.066 | 2.21 | **2.419** | 0.145 | 0.822 | 0.222 | 10.3 | 191.0 | 18.6 | 6.41 |
| | | 1 | 0.059 | 2.00 | **2.523** | 0.150 | 0.857 | 0.213 | 10.6 | 205.2 | 19.7 | 6.82 |
| | | 2 | 0.057 | 2.21 | **2.530** | 0.147 | 0.876 | 0.210 | 9.3 | 178.2 | 19.2 | 6.02 |
| | Niv_K | 0 | 0.058 | **1.78** | 2.498 | 0.147 | **0.836** | 0.229 | 9.8 | 185.4 | 19.2 | 6.34 |
| | | 1 | 0.067 | **2.11** | 2.507 | 0.151 | **0.840** | 0.213 | 10.6 | 202.6 | 19.3 | 6.79 |
| | | 2 | 0.058 | **2.52** | 2.467 | 0.145 | **0.878** | 0.202 | 9.9 | 186.3 | 19.0 | 6.13 |
| | Niv_Mg | 0 | 0.061 | 2.15 | 2.491 | 0.147 | 0.858 | 0.211 | **9.8** | **185.0** | 19.2 | **6.24** |
| | | 1 | 0.061 | 2.13 | 2.490 | 0.148 | 0.845 | 0.218 | **10.4** | **197.9** | 19.2 | **6.60** |

A regression analysis done according Foster method gives the following trend for both the trials:

(DA5D x DA3D) x LM2T selfed (Table 18):

In such planting material, very high yield is obtained without fertiliser and optimum crop is reached with the maximum rates of fertilizers (nearly 8 tons CPO/ha/year but 7.3 tons is reached with only 0.5kg of Kieserite).

Table 18: Multiple regression on ALCP 61 results

| Treatments | | | | CPO / ha / yr |
|---|---|---|---|---|
| N | P | K | Mg | |
| 0 | 0 | 0 | 1 | 7.34 |
| 0 | 0 | 0 | 2 | 7.50 |
| 2 | 2 | 0 | 2 | 7.86 |
| 2 | 2 | 2 | 2 | 7.96 |

(DA5D x DA3D) x LM311P (Table 19):

The results appear more contrasted with ALCP 62. The yield is lower without fertilizer, but response to the phosphorus application is vigorous (1.4 tons CPO/ha/year). A highest rate of phosphorus fertilization gives optimum yield (7.68 tons CPO/ha/year), but increasing the nitrogen and / or the potassium uptake is depressing strongly the yield by more than 1 tons CPO/ha.

Table 19: Multiple regression on ALCP 62 results

| Treatments | | | | CPO / ha / yr |
|---|---|---|---|---|
| N | P | K | Mg | |
| 0 | 0 | 0 | 0 | 6.23 |
| 0 | 0 | 1 | 0 | 6.56 |
| 0 | 0 | 1 | 1 | (6.83) |
| 0 | 1 | 1 | 0 | 6.93 |
| 0 | 1 | 1 | 1 | 7.21 |
| 1 | 1 | 1 | 1 | 7.57 |
| 1 | 2 | 1 | 1 | 7.68 |
| 1 | 2 | 2 | 1 | 6.61 |
| 2 | 2 | 2 | 1 | 6.12 |

Finally, the (DA5D x DA3D) x LM2T selfed material could reach nearly 8 tons CPO/ha, the corresponding total fertilizer rate is attaining 8.5 kg. The optimum potential of (DA5D x DA3D) x LM311P reaches 7.7 tons CPO/ha, but corresponding total fertilizer rate is only 4 kg per tree, saving particularly 2 kg in Urea and Potassium Chlorine. However, LM311P appears to be hungrier for P than LM2T and 1.5 kg RP does not appear sufficient to fulfil LM311P phosphorus requirements. Adding more N or K does not improve the yield as P is the most limiting factor which will need to be corrected before any effect of N or K can be seen.

LM311P as ancestor has been regularly cited in association with LM5T for its particular behavior in the mineral nutrition. The results presented above, should be confirmed with more experiments. But they are clear food for thought that some material could better use specific nutrient than others, and there is a very wide scope of investigation to adapt specific material to specific natural resources.

## CONCLUSION

According this short study, it appears that in PT Socfindo germplasm, the Deli group ancestor families and the African ancestor families could be gather together within specific groups corresponding to their relative leaf nutrient contents: particularly families deriving from DA115D, BB206D from A group, LM5T, LM311P and Yangambi sources from B group display very specific characteristics.

According the comparison between the Aek Loba Timur project and the commercial plantings, some families such as DA115D or BB206D, for example, could have different nutritional behavior according the calcium context.

The interesting relationship between nitrogen and Total Leaf Cation proposed by Foster on DAMI materials should be studied more deeply on more compact materials like Deli x La Mé ones.

After proving the genetic influence on the critical levels, new analyses realised on two fertiliser trials at Aek Loba give food for thought that the fertilisation management should be apprehended in taking into account the origin of the material and this might be even more important in the future if cloning material is used.

In that matter, PT Socfindo and CIRAD are implementing a specific set of experiments studying the mineral nutrition – genotype interaction focusing on the nitrogen and the potassium nutrition, and the fertilisation by using ancestors that have a contrasted behavior as shown in this paper.

## ACKOWLEDGEMENTS

The work described in this paper was carried out under a scientific collaboration agreement between Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and PT Socfin Indonesia (Socfindo). Special thanks are provided to Dr Foster and Dr Flori (Cirad) for their advice and support for presented statistical analyses. The authors wish to thank the management of Socfindo and CIRAD for permission to publish these results.

**REFERENCES**


CALIMAN J.P., DANIEL C. and TAILLIEZ B. (1994). Oil Palm mineral nutrition. **Plantations, recherche, développement**, 1 (3): 36-54.

CORLEY R.H.V. and P.B. TINKER (2003). The Oil Palm (Fourth Edition) – Blackwell Science Editor – London. 562 p.

FOSTER H.L. (2003). Assessment of Oil Palm Fertilizer Requirements in "**Oil Palm – Management for large and sustainable yields**" FAIRHURST T. And HÄRDTLER R. Editors; PPI / PPIC – Singapore. 382 p.

FOSTER H.L. and PRABOWO N.E. (1996). Variation in the potassium fertiliser requirements of oil palm in North Sumatra. **1996 PORIM International Oil Palm Congress on "Competitiveness for the 21st century"**, 23-28 September 1996, Kuala Lumpur, Malaysia.

HARTLEY C.W.S., 1988. The Oil Palm. Longman, London, UK. (3rd ed.) 761 p.

JACQUEMARD J.C., EDYANA SURYANA and ASMADY (2000). Aek Loba Timur project: a new step for the oil palm (*Elaeis guineensis* Jacq.) improvement at PT Socfindo. **2001 PIPOC on "Cutting-Edge Technologies for Sustained Competitiveness"**, 20 – 22 August 2001, Kuala Lumpur, Malaysia.

JACQUEMARD J.C., TAILLIEZ B., DADANG K., OUVRIER M and ASMADY (2002). Oil palm (*Elaeis guineensis* Jacq.) nutrition: Planting material effect. **2002 International Oil Palm Conference and Exhibition,** 8 – 12 July 2002, Bali, Indonesia

OLLAGNIER M., DANIEL C., FALLAVIER P. and OCHS R. (1987). The influence of climate and soil on potassium critical level in oil palm leaf analysis. **Oléagineux**, 42 (12): 435-447.

OCHS R. and OLLIVIN J. (1977). Leaf analysis for the control of nutrition in oil palm plantation – taking of leaf samples. **Oléagineux**, 32 (5): 211 – 216

TAMPUBOLON F.H., DANIEL C. And OCHS R. (1990). Oil palm responses to nitrogen and phosphate fertiliser in Sumatra. **Oléagineux**, 45: 475 - 486

# Annex 1

## Fertilisation tables for the Aek Loba Timur Project at immature stage

**Application in kg/palm/year of element equivalent**

***1995 plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.478 | 0.460 | 0.805 |
| Phosphorus ($P_2O_5$) | 0.448 | 0.315 | 0.158 |
| Potassium ($K_2O$) | 0.360 | 0.450 | 0.450 |
| Magnesium (MgO) | 0.156 | 0.195 | 0.000 |
| Boron ($B_2O_5$) | 0.024 | 0.046 | 0.046 |

***1997 April plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.634 | 0.722 | 1.150 |
| Phosphorus ($P_2O_5$) | 0.525 | 0.263 | 0.175 |
| Potassium ($K_2O$) | 0.540 | 1.560 | 1.200 |
| Magnesium (MgO) | 0.120 | 0.200 | 0.100 |
| Boron ($B_2O_5$) | 0.046 | 0.041 | 0.046 |

***1997 Oct – Nov plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.478 | 0.549 | 1.150 |
| Phosphorus ($P_2O_5$) | 0.448 | 0.263 | 0.175 |
| Potassium ($K_2O$) | 0.360 | 1.440 | 1.200 |
| Magnesium (MgO) | 0.125 | 0.260 | 0.130 |
| Boron ($B_2O_5$) | 0.026 | 0.041 | 0.046 |

***1998 May planting***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.651 | 1.150 | 1.150 |
| Phosphorus ($P_2O_5$) | 0.519 | 0.175 | 0.000 |
| Potassium ($K_2O$) | 1.004 | 1.200 | 0.600 |
| Magnesium (MgO) | 0.202 | 0.100 | 0.100 |
| Boron ($B_2O_5$) | 0.037 | 0.046 | 0.046 |

***1998 Oct – Nov plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.362 | 0.759 | 1.265 |
| Phosphorus ($P_2O_5$) | 0.460 | 0.263 | 0.000 |
| Potassium ($K_2O$) | 0.192 | 1.440 | 1.200 |
| Magnesium (MgO) | 0.096 | 0.200 | 0.100 |
| Boron ($B_2O_5$) | 0.015 | 0.041 | 0.046 |

***1999 March – April plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.251 | 1.035 | 1.380 |
| Phosphorus ($P_2O_5$) | 0.286 | 0.263 | 0.350 |
| Potassium ($K_2O$) | 0.617 | 1.440 | 1.320 |
| Magnesium (MgO) | 0.137 | 0.200 | 0.300 |
| Boron ($B_2O_5$) | | 0.041 | 0.046 |

***2000 April – May plantings***

| Elements | N0 / N1 | N2 | N3 |
|---|---|---|---|
| Nitrogen | 0.268 | 1.196 | 1.288 |
| Phosphorus ($P_2O_5$) | 0.263 | 0.300 | 0.300 |
| Potassium ($K_2O$) | 0.065 | 1.080 | 1.320 |
| Magnesium (MgO) | 0.043 | 0.180 | 0.300 |
| Boron ($B_2O_5$) | 0.008 | 0.076 | 0.103 |

# Annex 2

## Leaf Cation balance data

**Leaf cation balance data for the A group origins at 3- years -old at the ALT project**

| Sub-Group | A origin | TLC | MG | MG/TLC | CA | CA/TLC | K | K/TLC |
|---|---|---|---|---|---|---|---|---|
| AN x Socfin | (TNR115xLM630D)I | 95.1 | 15.7 | 16.5% | 53.3 | 56.0% | 26.1 | 27.4% |
| Socfindo | BB126DxBB150D | 92.2 | 17.0 | 18.5% | 45.4 | 49.2% | 29.8 | 32.3% |
| | BB177DxBB129D | 92.0 | 15.6 | 17.0% | 49.2 | 53.5% | 27.2 | 29.5% |
| | BB206Dselfed | 93.2 | 16.9 | 18.1% | 48.2 | 51.7% | 28.2 | 30.2% |
| Dabou | (DA5DxDA3D)selfed | 101.7 | 21.2 | 20.8% | 58.7 | 57.7% | 21.9 | 21.5% |
| | DA 10 D | 97.4 | 16.0 | 16.4% | 56.1 | 57.6% | 25.3 | 26.0% |
| | DA10DxDA3D | 95.5 | 17.9 | 18.7% | 54.9 | 57.4% | 22.8 | 23.9% |
| | DA10DxDA115D | 102.8 | 19.4 | 18.9% | 61.2 | 59.6% | 22.1 | 21.5% |
| | DA 115 D | 107.0 | 19.9 | 18.6% | 66.9 | 62.5% | 20.2 | 18.9% |
| | DA115D II | 106.3 | 17.7 | 16.6% | 66.5 | 62.5% | 22.1 | 20.8% |
| | DA115Dselfed | 104.0 | 19.6 | 18.8% | 63.6 | 61.2% | 20.8 | 20.0% |
| | DA115DxDA3D | 100.8 | 19.2 | 19.0% | 61.8 | 61.4% | 19.8 | 19.6% |
| Socfin x Dabou | LM269DxDA115D | 101.9 | 17.4 | 17.1% | 62.7 | 61.5% | 21.7 | 21.3% |
| | LM269DxDA128D | 98.6 | 22.2 | 22.5% | 53.4 | 54.1% | 23.0 | 23.3% |
| Dabou | DA300DxDA128D | 95.6 | 18.2 | 19.0% | 54.7 | 57.2% | 22.7 | 23.8% |
| | DA551DxDA767D | 104.2 | 22.8 | 21.9% | 62.0 | 59.5% | 19.4 | 18.6% |
| Socfin | LM404Dselfed | 97.3 | 19.2 | 19.7% | 54.7 | 56.2% | 23.4 | 24.1% |
| Socfin x Dabou | LM404DxDA10D | 97.2 | 17.7 | 18.2% | 56.1 | 57.7% | 23.4 | 24.1% |
| | LM404DxDA3D | 93.8 | 16.7 | 17.8% | 53.5 | 57.0% | 23.7 | 25.2% |

**Leaf cation balance data for the A group origins at 5 to 7- years -old at the ALT project**

| Sub-Group | A origin | TLC | MG | MG/TLC | CA | CA/TLC | K | K/TLC |
|---|---|---|---|---|---|---|---|---|
| AN x Socfin | (TNR115xLM630D)I | 83.0 | 13.3 | 16.0% | 43.9 | 53.0% | 25.8 | 31.1% |
| Socfindo | BB126DxBB150D | 80.2 | 14.1 | 17.5% | 36.9 | 45.9% | 29.3 | 36.5% |
| | BB177DxBB129D | 80.3 | 12.4 | 15.5% | 39.6 | 49.3% | 28.3 | 35.2% |
| | BB206Dselfed | 82.0 | 13.2 | 16.1% | 39.0 | 47.6% | 29.8 | 36.4% |
| Dabou | (DA5DxDA3D)selfed | 87.1 | 16.0 | 18.3% | 45.4 | 52.1% | 25.8 | 29.6% |
| | DA 10 D | 83.6 | 13.3 | 16.0% | 42.8 | 51.2% | 27.5 | 32.9% |
| | DA10DxDA3D | 83.3 | 13.8 | 16.6% | 45.2 | 54.2% | 24.3 | 29.2% |
| | DA10DxDA115D | 86.0 | 15.0 | 17.4% | 46.7 | 54.3% | 24.3 | 28.3% |
| | DA 115 D | 90.3 | 16.0 | 17.8% | 50.8 | 56.3% | 23.4 | 25.9% |
| | DA115D II | 84.7 | 14.1 | 16.6% | 45.8 | 54.0% | 24.9 | 29.4% |
| | DA115Dselfed | 87.7 | 16.0 | 18.3% | 49.0 | 55.9% | 22.6 | 25.8% |
| | DA115DxDA3D | 85.2 | 14.2 | 16.6% | 48.8 | 57.3% | 22.2 | 26.0% |
| Socfin x Dabou | LM269DxDA115D | 85.1 | 14.8 | 17.4% | 45.9 | 54.0% | 24.3 | 28.6% |
| | LM269DxDA128D | 86.2 | 17.0 | 19.8% | 45.0 | 52.3% | 24.1 | 28.0% |
| Dabou | DA300DxDA128D | 83.6 | 15.6 | 18.6% | 42.8 | 51.2% | 25.3 | 30.2% |
| | DA551DxDA767D | 91.1 | 21.4 | 23.5% | 51.5 | 56.5% | 18.3 | 20.0% |
| Socfin | LM404Dselfed | 84.6 | 15.3 | 18.1% | 45.0 | 53.2% | 24.3 | 28.7% |
| Socfin x Dabou | LM404DxDA10D | 85.2 | 14.9 | 17.5% | 45.5 | 53.4% | 24.8 | 29.1% |
| | LM404DxDA3D | 82.1 | 13.5 | 16.4% | 43.8 | 53.4% | 24.7 | 30.1% |

**Leaf cation balance data for the B group origins at 3- years -old at the ALT project**

| Sub Group | B origin | TLC | MG | MG/TLC | CA | CA/TLC | K | K/TLC |
|---|---|---|---|---|---|---|---|---|
| LM | LM 2 T | 101.2 | 17.5 | 17.3% | 60.4 | 59.7% | 23.2 | 23.0% |
| | LM2Tselfed | 98.8 | 17.4 | 17.7% | 58.7 | 59.4% | 22.7 | 23.0% |
| | (LM2T)II | 97.1 | 17.7 | 18.2% | 56.6 | 58.3% | 22.8 | 23.5% |
| | LM2TxLM10T | 98.8 | 18.0 | 18.2% | 58.9 | 59.6% | 21.8 | 22.1% |
| | LM2TxLM5T | 99.4 | 17.7 | 17.8% | 58.7 | 59.0% | 23.0 | 23.2% |
| | LM5TxLM2T | 96.7 | 17.0 | 17.6% | 56.0 | 57.9% | 23.7 | 24.5% |
| | LM5Tselfed | 102.3 | 19.3 | 18.8% | 62.6 | 61.2% | 20.4 | 20.0% |
| | LM5TxLM311P | 104.6 | 21.8 | 20.8% | 61.2 | 58.5% | 21.6 | 20.7% |
| | LM5TxLM10T | 97.4 | 18.5 | 19.0% | 57.6 | 59.1% | 21.3 | 21.9% |
| | LM10Tselfed | 102.7 | 18.8 | 18.4% | 62.3 | 60.7% | 21.5 | 20.9% |
| LM x SI | (LM2TxSI10T)I | 96.4 | 18.4 | 19.1% | 53.1 | 55.1% | 24.8 | 25.7% |
| SOCFINDO | BB85Tselfed | 93.3 | 18.7 | 20.0% | 44.9 | 48.1% | 29.7 | 31.8% |
| | BB85TxBB20P | 90.7 | 16.5 | 18.2% | 43.1 | 47.5% | 31.1 | 34.3% |
| YA | LM238TxLM511P | 97.8 | 21.3 | 21.8% | 53.3 | 54.5% | 23.1 | 23.7% |
| | LM718TxLM238T | 95.4 | 19.8 | 20.8% | 48.9 | 51.2% | 26.7 | 28.0% |
| | PO 4157 T | 93.4 | 16.3 | 17.5% | 52.6 | 56.4% | 24.5 | 26.2% |
| NIFOR | PO1879TxPO1876T | 93.6 | 15.9 | 17.0% | 47.2 | 50.5% | 30.5 | 32.6% |
| Other | PO 3660 P | 100.3 | 23.6 | 23.6% | 52.7 | 52.6% | 23.9 | 23.9% |
| | BB 106 T | 85.5 | 13.4 | 15.7% | 44.6 | 52.2% | 27.5 | 32.2% |
| | FR10 | 107.3 | 21.2 | 19.7% | 67.2 | 62.7% | 18.9 | 17.6% |
| | ?xLM9T | 94.1 | 19.1 | 20.3% | 53.6 | 56.9% | 21.5 | 22.8% |
| | FR9 | 107.6 | 21.3 | 19.8% | 64.9 | 60.3% | 21.4 | 19.9% |
| | LM426Tselfed | 104.1 | 19.0 | 18.3% | 60.8 | 58.4% | 24.3 | 23.3% |
| | LM2TxLM231T | 108.7 | 25.4 | 23.4% | 62.3 | 57.4% | 20.9 | 19.2% |

**Leaf cation balance data for the B group origins at 5 to 7- years -old at the ALT project**

| Sub Group | B origin | TLC | MG | MG/TLC | CA | CA/TLC | K | K/TLC |
|---|---|---|---|---|---|---|---|---|
| LM | LM 2 T | 86.2 | 14.4 | 16.7% | 46.0 | 53.3% | 25.9 | 30.0% |
| | LM2Tselfed | 83.7 | 14.0 | 16.7% | 44.8 | 53.5% | 24.9 | 29.7% |
| | (LM2T)II | 83.0 | 14.2 | 17.2% | 43.2 | 52.1% | 25.5 | 30.8% |
| | LM2TxLM10T | 84.5 | 14.0 | 16.6% | 46.5 | 55.1% | 24.0 | 28.4% |
| | LM2TxLM5T | 85.0 | 14.3 | 16.8% | 45.7 | 53.8% | 24.9 | 29.3% |
| | LM5TxLM2T | 83.2 | 12.4 | 14.9% | 43.9 | 52.8% | 26.8 | 32.2% |
| | LM5Tselfed | 87.0 | 15.4 | 17.7% | 49.0 | 56.3% | 22.7 | 26.0% |
| | LM5TxLM311P | 89.7 | 17.7 | 19.7% | 48.4 | 53.9% | 23.6 | 26.3% |
| | LM5TxLM10T | 84.0 | 15.0 | 17.8% | 45.6 | 54.3% | 23.4 | 27.9% |
| | LM10Tselfed | 86.5 | 14.1 | 16.3% | 48.5 | 56.1% | 23.9 | 27.7% |
| LM x SI | (LM2TxSI10T)I | 83.6 | 16.0 | 19.2% | 41.9 | 50.2% | 25.6 | 30.6% |
| SOCFINDO | BB85Tselfed | 80.3 | 15.1 | 18.8% | 36.2 | 45.0% | 29.1 | 36.2% |
| | BB85TxBB20P | 80.5 | 14.2 | 17.6% | 35.2 | 43.8% | 31.1 | 38.6% |
| YA | LM238TxLM511P | 86.8 | 18.3 | 21.0% | 45.4 | 52.3% | 23.1 | 26.6% |
| | LM718TxLM238T | 83.8 | 16.0 | 19.1% | 41.2 | 49.1% | 26.6 | 31.7% |
| | PO 4157 T | 85.6 | 15.0 | 17.5% | 45.3 | 53.0% | 25.2 | 29.5% |
| NIFOR | PO1879TxPO1876T | 82.2 | 11.8 | 14.3% | 39.1 | 47.5% | 31.4 | 38.2% |
| Other | PO 3660 P | 82.3 | 15.2 | 18.5% | 40.1 | 48.7% | 27.0 | 32.8% |
| | BB 106 T | 75.9 | 11.1 | 14.6% | 36.8 | 48.4% | 28.1 | 37.0% |
| | FR10 | 88.6 | 18.5 | 20.9% | 47.2 | 53.3% | 22.9 | 25.8% |
| | ?xLM9T | 81.1 | 15.6 | 19.3% | 41.5 | 51.2% | 23.9 | 29.5% |
| | FR9 | 91.1 | 17.5 | 19.3% | 50.0 | 54.9% | 23.5 | 25.8% |
| | LM426Tselfed | 86.5 | 15.0 | 17.3% | 46.5 | 53.7% | 25.0 | 28.9% |
| | LM2TxLM231T | 92.0 | 18.8 | 20.5% | 49.3 | 53.6% | 23.9 | 25.9% |

**Leaf Cation balance data for the A group families in the commercial plantings at 3-years -old**

| Sub-group | A origin | TLC | K/TLC | Ca/TLC | Mg/TLC |
|---|---|---|---|---|---|
| SOCFINDO | BB126D x BB150D | 95.2 | 29.6 | 46.6 | 23.8 |
| | BB206D selfed | 98.6 | 27.5 | 49.6 | 23.0 |
| DABOU | DA115D selfed | 92.4 | 27.1 | 45.7 | 27.2 |
| | DA115D x (DA5DxDA3D) | 94.4 | 30.5 | 46.4 | 23.2 |
| | DA5D x DA3D | 90.3 | 28.9 | 44.5 | 26.6 |
| SOCFIN x DABOU | (DA5D x DA3D) x (LM404D x DA10D) | 89.6 | 28.4 | 45.6 | 25.9 |
| | LM404D x (DA5DxDA3D) | 97.6 | 25.5 | 53.4 | 21.1 |
| | LM404D x DA10D | 95.4 | 27.7 | 47.8 | 24.6 |
| | LM404D x LM270D | 94.4 | 29.4 | 40.5 | 30.1 |

**Leaf Cation balance data for the B group families in the commercial plantings at 3-years -old**

| Sub-group | A origin | TLC | K/TLC | Ca/TLC | Mg/TLC |
|---|---|---|---|---|---|
| La Mé | LM2Tself | 91.4 | 28.1 | 46.2 | 25.7 |
| | LM5Tself | 90.8 | 28.0 | 45.8 | 26.1 |
| | LM5TxLM311P | 93.6 | 24.0 | 50.1 | 25.9 |
| Yangambi | LM718Tself | 98.6 | 27.5 | 49.6 | 23.0 |
| | LM718TxLM238T | 94.7 | 29.5 | 42.6 | 28.0 |